



# TRIP OF APD-HEYWOOD- TARRONE NO.1 500 KV LINE, MOORABOOL-TARRONE 500 KV LINE AND APD POTLINES ON 13 FEBRUARY 2015

AN AEMO POWER SYSTEM OPERATING INCIDENT REPORT  
FOR THE NATIONAL ELECTRICITY MARKET

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# IMPORTANT NOTICE

## Purpose

AEMO has prepared this document to provide information about this particular Power System Operating Incident.

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## VERSION RELEASE HISTORY

VERSION	DATE	BY	CHANGES	CHECKED BY	AUTHORISED BY
1	25 August 2015	R Burge	FINAL	J Lu	P Biddle

## INCIDENT CLASSIFICATIONS

<b>Time and date and of incident</b>	0958 hrs Friday 13 February 2015
<b>Region of incident</b>	Victoria
<b>Affected regions</b>	Victoria
<b>Event type</b>	TL – Loss of transmission element(s) and load interruption
<b>Primary cause</b>	PTN & CTRL – Protection and Control
<b>Generation Impact</b>	The following generators were disconnected as a result of this incident: Macarthur wind farm Portland wind farm
<b>Customer Load Impact</b>	APD No.1 and No.2 potlines were disconnected as a result of this incident
<b>Associated reports</b>	Nil

## ABBREVIATIONS

Abbreviation	Term
<b>AEMO</b>	Australian Energy Market Operator
<b>APD</b>	Alcoa Portland
<b>ARPS</b>	Anti-Resonance Protection Scheme
<b>CB</b>	Circuit Breaker
<b>Heywood</b>	Heywood Terminal Station
<b>kV</b>	Kilovolt
<b>Line 1</b>	APD – Heywood No.1 and Heywood – Tarrone No.1 500 kV lines
<b>Line 2</b>	APD – Heywood No.2 500 kV line
<b>Moorabool</b>	Moorabool Terminal Station
<b>MW</b>	Megawatt
<b>NER</b>	National Electricity Rules
<b>Tarrone</b>	Tarrone Terminal Station



# 1. INTRODUCTION

This report reviews a power system operating incident on Friday 13 February 2015 in Victoria.

The incident involved the simultaneous trip of two transmission lines, which resulted in disconnection of generators and load. The incident was caused by malfunction of a protection relay at Heywood Terminal Station (Heywood).

AEMO is required to assess power system security over the course of this incident as the incident is classified as a non-credible contingency under the National Electricity Rules (NER).<sup>1</sup> Specifically, AEMO must 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.<sup>2</sup>

AEMO concluded that:

- A faulty protection relay at Heywood incorrectly operated, tripping two transmission lines.
- Generators and loads connected to the tripped lines were disconnected as a result.
- The issue was resolved by replacing the faulty protection relay.
- Power system security was restored to a secure operating state within the required timeframe of 30 minutes following the incident.

This report is based on information provided by AusNet Services<sup>3</sup> and AEMO. National Electricity Market time (Australian Eastern Standard Time) is used throughout.

# 2. THE INCIDENT

At 0616 hrs on Friday 13 February 2015 the APD-Heywood No.2 500 kV line (Line 2) was taken out of service for planned maintenance.

At 0958 hrs the APD-Heywood No.1 and Heywood-Tarrone No.1 500 kV lines (Line 1) and the Moorabool-Tarrone 500 kV lines tripped simultaneously, isolating Portland wind farm (9 MW) and Macarthur wind farm (241 MW).

As this incident occurred during the planned outage of Line 2, APD No.1 and No.2 potlines were disconnected from 475 MW.

The Moorabool-Tarrone 500 kV line was restored at 1157 hrs and Line 1 at 1546 hrs. Line 2 was restored at 1225 hrs, returning supply to APD. AEMO gave permission to restore the APD No.1 and No.2 potlines at 1310 and 1320 hrs respectively.

The reason for investigating this incident is that multiple transmission elements tripped simultaneously, potentially threatening power system security. This is known in power system security terms as a 'non-credible contingency'.<sup>4</sup>

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1 Clause 4.8.15(a)(1)(i) and AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.

2 NER Clause 4.8.15 (b)

3 AusNet Services is a Transmission Network Service Provider in Victoria. Information provided by AusNet Services has been provided on a without prejudice basis and nothing in this report is intended to constitute, or may be taken by any person as constituting, an admission of fault, liability, wrongdoing, negligence, bad faith or the like on behalf of AusNet Services (or its respective associated companies, businesses, partners, directors, officers or employees).

4 NER Clause 4.2.3 - Credible and non-credible contingency events; AEMO Power System Security Guidelines, Section 10 - Definition of a non-credible contingency events



See Appendix 1 for a power system diagram illustrating the incident, and Appendix 2 for a chronological log of the incident.

## 3. AUSNET INVESTIGATION

AusNet Services investigated this incident and found that Line 1 initially tripped on red phase only. A current differential protection relay at Heywood malfunctioned, opening red phase of 500 kV Circuit Breaker 210. This relay should not have operated as there was no fault on the line.

The following occurred as a result of the single phase trip on Line 1:

- 500 kV Circuit Breaker 5500 at APD opened on red phase only via an inter-trip signal from Heywood (as designed).
- No trip was initiated at Tarrone end of the line as there was no fault on Line 1. Hence the Circuit breakers at Tarrone did not operate.

The Anti-Resonance Protection Scheme<sup>5</sup> (ARPS) then operated as designed because a high voltage was detected at Heywood from the Tarrone end of this line since the circuit breakers had not opened. The ARPS operated as designed:

- Tripped Line 1 on all 3 phases.
- Tripped the Moorabool-Tarrone 500 kV line on all three phases.
- Closed the centre circuit breaker at Tarrone.

As described above the simultaneous tripping of Line 1 and the Moorabool-Tarrone 500 kV line occurred. This resulted in disconnection of Portland and Macarthur wind farms and APD No.1 and No.2 potlines.

AusNet replaced the faulty protection relay at Heywood on 26 February 2015, 13 days after the incident, after receiving recommendation from the relay manufacturer. AusNet undertook detailed investigation and could not confirm the cause earlier as they had to rule out the possibility of human error due to planned maintenance at the time of the incident.

### 3.1 Recall of Line 2

The APD-Heywood No.2 500 kV line (Line 2) was taken out of service for planned maintenance at 0616 hrs on 13 February 2015. This outage was approved by AEMO with an estimated recall time of 2 hours.

Following the trip of Line 1, AusNet recalled Line 2 from the planned outage at 0959 hrs. Line 2 was returned to service at 1225 hrs, exceeding the estimated outage recall time. This delayed load restoration to APD. Given the complexity of the maintenance involved to restore the load, AusNet Services underestimated the time required to recall the outage. For future outages, AusNet will review its processes and estimate the outage recall time after taking into account the complexity of maintenance required.

<sup>5</sup> See Appendix 4 for details on the operation of the Anti-Resonance Protection Scheme

## 4. POWER SYSTEM SECURITY

This section assesses how AEMO managed power system security over the course of the incident<sup>6</sup>.

- On Friday 13 February 2015 at 1010 hrs (approximately 12 minutes after the incident) AEMO invoked constraint sets F-I-HYSE<sup>7</sup>, F-V-HYTR<sup>8</sup>, F-V-MLTR<sup>9</sup>, I-HYSE<sup>10</sup>, V-HYTR<sup>11</sup>, V-MACARTHUR\_ZERO<sup>12</sup> and V-MLTR<sup>13</sup>. This action ensured that the power system returned to a secure operating state.
- A number of constraints were violated in dispatch intervals ending 1015, 1020 and 1025 hrs (see Appendix 3). The main cause of the constraint violations were due to constraints on the VIC-SA Heywood interconnector and the required change in direction of interconnector flow. The power system was returned to a secure state at 1025 hrs, indicating the power system was insecure for up to 27 minutes.<sup>14</sup>
- At 1103 hrs (approximately 65 minutes after the incident) AEMO issued Market Notice 48158 to notify the market of a non-credible contingency event<sup>15</sup>.
- At 1157 hrs the Moorabool-Tarrone 500 kV line was returned to service and the Heywood-Tarrone section of Line 1 was restored at 1205 hrs. AEMO then revoked constraint sets F-I-HYSE, F-V-HYTR, F-V-MLTR, I-HYSE, V-HYTR and V-MLTR at 1215 hrs.
- At 1225 hrs Line 2 was restored, returning supply to APD. AEMO revoked constraint set V-MACARTHUR\_ZERO after Tarrone No.1 500 kV busbar was restored.
- At 1240 hrs AEMO invoked constraint set V-APHY1\_2<sup>16</sup> with the APD-Heywood section of Line 1 still out of service.
- At 1301 hrs AEMO issued Market Notice 48162 to inform the market that the cause of the event had been identified and AEMO would not reclassify the event as a credible contingency<sup>17</sup>. This was based on advice from AusNet that the tripping of two lines was due to operation of the ARPS following the tripping of Line 1 as designed.
- AEMO gave permission to restore the APD No.1 and No.2 potlines at 1310 and 1320 hrs respectively.
- At 1546 hrs Line 1 was returned to service. AEMO revoked constraint set V-APHY1\_2 at 1600 hrs.
- At 1905 hrs AEMO issued Market Notice 48167 to inform the market that the cause of the event had not been identified and the event would be reclassified as a credible contingency. AusNet advised that the cause of the initial trip of Line 1 remained unknown and it was possible that the non-credible contingency may reoccur.

<sup>6</sup> AEMO is responsible for power system security in the NEM and is required to operate the power system in a secure operating state (NER Clause 4.2.4 (a)). AEMO must thereby ensure that the power system is maintained in, or returned to, a secure operating state following a contingency event.

<sup>7</sup> Out = one Heywood to South East (HYTS-SESS) 275 kV line – FCAS requirements

<sup>8</sup> Out = one Heywood to Tarrone (HYTS-TRTS) No.1 500 kV line – FCAS requirements

<sup>9</sup> Out = one Moorabool to Tarrone (MLTS-TRTS) No.1 500 kV line – FCAS requirements

<sup>10</sup> Outage = Heywood to South East 275 kV line

<sup>11</sup> Outage = Heywood to Tarrone (HYTS-TRTS) No.1 500 kV line

<sup>12</sup> Macarthur wind farm upper limit of 0 MW

<sup>13</sup> Outage = Moorabool to Tarrone (MLTS-TRTS) No.1 500 kV line

<sup>14</sup> AEMO is required to return the power system to a secure state within thirty minutes following a contingency event - NER Clause 4.2.6 (b)

<sup>15</sup> 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 10.3

<sup>16</sup> Out = Alcoa Portland to Heywood (APD-HYTS) No.1 500 kV line, both HYTS 500/275 kV txfrms in service

<sup>17</sup> AEMO is required to assess whether or not to reclassify a non credible contingency event as a credible contingency - NER Clause 4.2.3A (c) - and to report how re-classification criteria were applied - NER Clause 4.8.15 (ca). AEMO has to determine if the condition that caused the non-credible contingency event has been resolved.



AusNet Services replaced the faulty protection relay at Heywood on 26 February 2015 once further investigations were undertaken and the relay manufacturer was consulted. At 1300 hours on 20 May 2015 AEMO issued Market Notice 48994 to inform the market that the cause of the event had been identified and resolved and the reclassification was cancelled. The reclassification could not be removed any earlier due to a delay in receiving confirmation from AusNet that the cause of the incident had been identified and resolved.

The power system was returned to a secure operating state within 27 minutes following occurrence of the non-credible contingency event. AEMO correctly assessed the incident and reclassified the incident as a credible contingency, and appropriate notifications were issued.

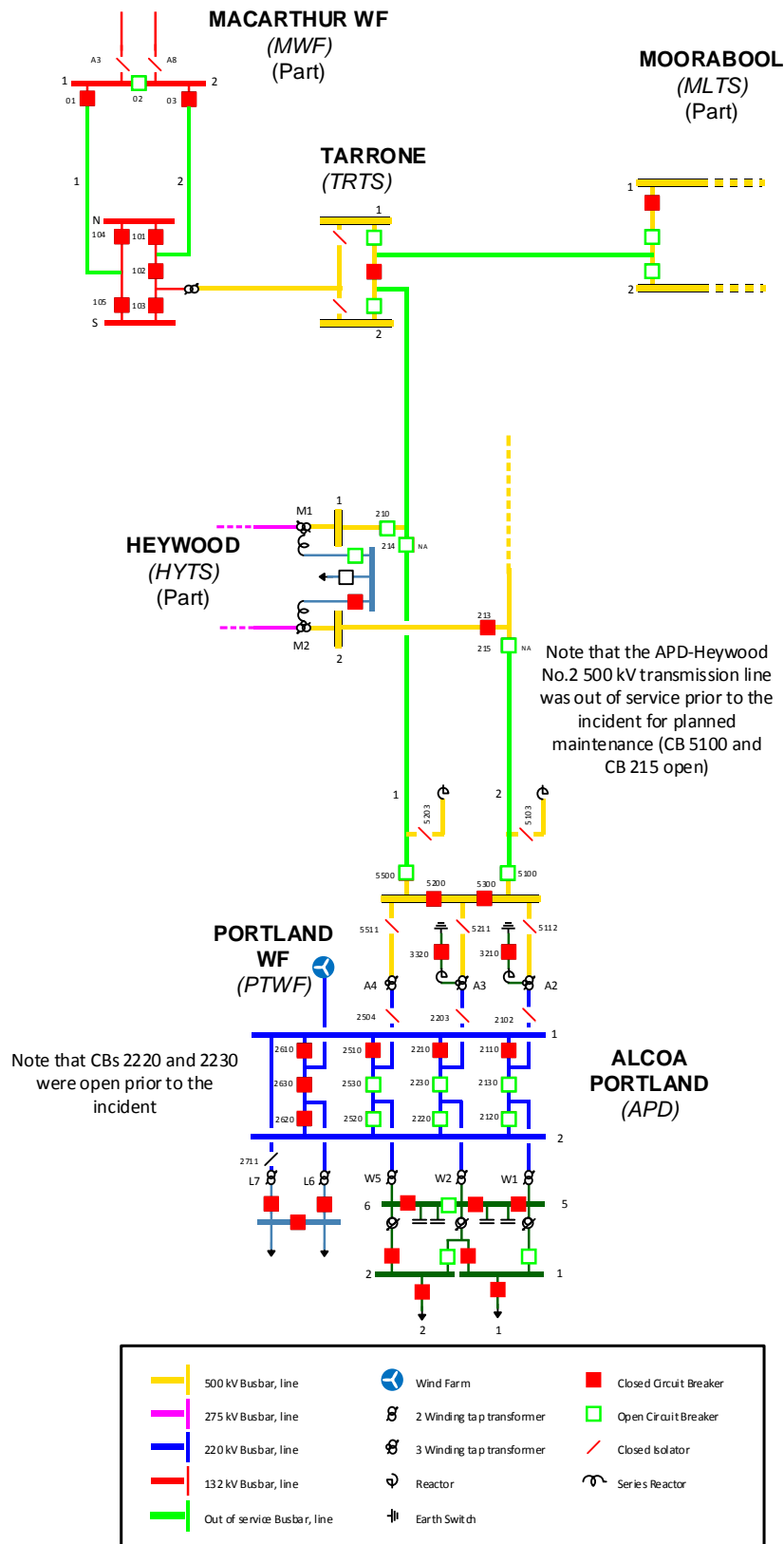
## 5. CONCLUSION

AEMO concluded that:

1. The APD-Heywood-Tarrone No.1 500 kV transmission line initially tripped on single phase due to malfunction of a protection relay at Heywood.
2. The Anti-Resonance Protection Scheme operated as designed and tripped Line 1 and the Moorabool-Tarrone 500 kV line on three phases, disconnecting Portland and Macarthur wind farms.
3. APD No.1 and No.2 potlines were disconnected from 475 MW due to a prior planned outage of the APD-Heywood No.2 500 kV line.
4. Line 2 was not recalled within the required two-hour time frame due to AusNet Services underestimating the complexity involved in suspending the maintenance and restoring the line.
5. The faulty protection relay at Heywood was replaced on 26 February 2015.
6. The power system was returned to a secure operating state within the required timeframes following the incident.
7. There are no outstanding issues to resolve as a result of this incident.

# APPENDIX 1 – POWER SYSTEM DIAGRAM

Figure 1 The power system after the incident







## APPENDIX 2 – INCIDENT EVENT LOG

**Table 1 Incident Log**

Time and Date	Event
0616 hrs 13 February 2015	APD-Heywood No.2 500 kV line out of service for planned maintenance with an estimated recall time of 2 hours
0958hrs 13 February 2015	APD-Heywood-Tarrone No.1 500 kV line and Moorabool-Tarrone 500 kV line tripped simultaneously, disconnecting: <ul style="list-style-type: none"> <li>Portland wind farm (9 MW)</li> <li>Macarthur wind farm (241 MW)</li> <li>APD No.1 and No.2 potlines (475 MW)</li> </ul>
0959 hrs 13 February 2015	AusNet recalled Line 2 from planned outage
1010 hrs 13 February 2015	AEMO invoked the following constraint sets to manage power system security: <ul style="list-style-type: none"> <li>F-I-HYSE</li> <li>F-V-HYTR</li> <li>F-V-MLTR</li> <li>I-HYSE</li> <li>V-HYTR</li> <li>V-MACARTHUR_ZERO</li> <li>V-MLTR</li> </ul>
1015 hrs 13 February 2015	Constraints violated during dispatch interval ending 1015 hrs (see Appendix 3)
1020 hrs 13 February 2015	Constraints violated during dispatch interval ending 1020 hrs (see Appendix 3)
1025 hrs 13 February 2015	Constraints violated during dispatch interval ending 1025 hrs (see Appendix 3)
1103 hrs 13 February 2015	AEMO issued Market Notice 48158 to inform the market of the non-credible contingency event
1157 hrs 13 February 2015	Moorabool-Tarrone 500 kV line returned to service
1205 hrs 13 February 2015	Heywood-Tarrone section of Line 1 returned to service
1215 hrs 13 February 2015	AEMO revoked the following constraint sets: <ul style="list-style-type: none"> <li>F-I-HYSE</li> <li>F-V-HYTR</li> <li>F-V-MLTR</li> <li>I-HYSE</li> <li>V-HYTR</li> <li>V-MLTR</li> </ul>
1225 hrs 13 February 2015	Line 2 restored, returning supply to APD
1240 hrs 13 February 2015	AEMO revoked constraint set V-MACARTHUR_ZERO after Tarrone No.1 500 kV busbar returned to service
1240 hrs 13 February 2015	AEMO invoked constraint set V-APHY1_2 after the Heywood transformers were returned to service, with APD-Heywood section of Line 1 still out of service
1301 hrs 13 February 2015	AEMO issued Market Notice 48162 to inform the market that the cause of the event had been identified and AEMO will not reclassify the event as a credible contingency
1305 hrs 13 February 2015	Alcoa informed AEMO that Portland wind farm is ok to return to service
1310 hrs 13 February 2015	AEMO gave permission to restore APD No.1 potline
1320 hrs 13 February 2015	AEMO gave permission to restore APD No.2 potline
1546 hrs 13 February 2015	Line 1 returned to service
1600 hrs 13 February 2015	AEMO revoked constraint set V-APHY1_2 after Line 1 returned to service
1905 hrs 13 February 2015	AEMO issued Market Notice 48167 to inform the market that the cause of the event had not been identified and the event will be reclassified as a credible contingency
26 February 2015	AusNet Services replaced the faulty protection relay at Heywood
1300 hrs 20 May 2015	AEMO issued Market Notice 48994 to inform the market that the cause of the event had been identified and resolved and the reclassification was cancelled



## APPENDIX 3 – VIOLATING CONSTRAINT EQUATIONS

**Table 2 Violating Constraints**

ConstraintID	Constraint Violation Degree		
	DI ending 1015 hrs	DI ending 1020 hrs	DI ending 1025 hrs
F_S++HYML_L5	21.3821	155.2694	44.3393
F_S++HYML_L6		220.0485	141.903
F_S++HYML_L60		164.3196	85.3197
F_S++HYSE_L5	21.3821	155.2694	44.3393
F_S++HYSE_L6		220.0485	141.903
F_S++HYSE_L60		164.3196	85.3197
S>>V_NIL_KHTB2_KHTB1		2.7375	
SV_200	40.0802	252.2113	174.633
SV_250		202.2113	124.633
V>>SML_NIL_7A	122.6374	7.6127	
V>>SML_NIL_7B	12.27		
V^SML_NIL_3	14.3885		
V^SML_NSWRB_2	35.1763	62.6844	
V_HYML1_3	472.75	420.75	354.75
V_HYML1_4	406.3428	229.3975	209.0912



## APPENDIX 4 – ANTI-RESONANCE PROTECTION SCHEME (ARPS)

When the APD-Heywood-Tarrone No.1 500 kV line is isolated, a near resonant condition exists between the line charging, the APD line shunt reactor and the capacitive coupling with the parallel 500 kV No.2 line. This can lead to dangerously high induced voltages on the APD-Heywood-Tarrone No.1 500 kV line when isolated. To remove this resonance, the APD No.1 500 kV line non-auto CB at Heywood is tripped whenever the APD-Heywood-Tarrone No.1 500 kV line is tripped, thus changing the connected line capacitance, and altering the resonant frequency.

The APD No.1 500 kV line non-auto CB at Heywood is not primarily used to clear faults, but it is designed to open for all situations following tripping of APD-Heywood-Tarrone No.1 500 kV including:

- Any other event causing a protection operation on the APD-Heywood-Tarrone No.1 500 kV line.
- Fault on APD-Heywood No. 1 500 kV line.
- Fault on Heywood-Tarrone No. 1 500 kV line.
- Failure of any CB on the APD-Heywood-Tarrone No.1 500 kV line following a fault on adjacent plant (i.e. Moorabool-Tarrone line, Heywood M1 transformer etc.).

Due to the consequences of the resonance, if the APD No.1 500 kV line non-auto CB at Heywood fails to open, the anti-resonance CB fail is triggered when either of the following conditions exist:

- APD No.1 500 kV line non-auto CB at Heywood is detected closed based on the CB contact status.

OR

- Presence of phase to ground voltage remaining above a threshold (set to 260 kV rms phase to ground) on the Heywood-Tarrone No.1 500 kV line (Heywood end) for more than 850 milliseconds.

On detection of CB Fail, the scheme effectively extends the isolated APD-Heywood-Tarrone No.1 500 kV line to Moorabool, by reconnecting the Moorabool-Tarrone line segment, thus increasing the capacitance and eliminating the resonance.

The CB Fail detection triggers the following sequence:

- Trip of Moorabool-Tarrone 500 kV transmission line at Tarrone and Moorabool.
- Closes the centre CB at Tarrone.