Power System Operation Incident Report – Trip of Alcoa Portland-Heywood-Tarrone No.1 500 kV Line and Tarrone-Moorabool No.1 500 kV line on 4 July 2013

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FINAL

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Incident Classifications

Date and time of incident	1451 hrs 4 July 2013
Region of incident	Victoria
Affected regions	Victoria and South Australia
Event type	TG – Loss of transmission elements and generating units.
Primary cause	PTN & CTR – Protection and Control
Impact	Very Significant – Loss of load or generation exceeding 250 MW.
Associated reports	Nil

Abbreviations and Symbols

Abbreviation	Term
AEMO	Australian Energy Market Operator
APD	Alcoa Portland
ARPS	Anti-Resonance Protection Scheme
CB	Circuit Breaker
DI	Dispatch Interval
EMMS	Electricity Market Management System
EMS	Energy Management System
HYTS	Heywood Terminal Station
kV	Kilovolt
LOR2	Lack of Reserve Condition 2 – defined in NER 4.8.4(c) - when *AEMO* considers that the occurrence of the *credible contingency event* which has the potential for the most significant impact on the *power system* is likely to require *involuntary load shedding*.
MW	Megawatt
MOPS	Mortlake Power Station
MLTS	Moorabool Terminal Station
NER	National Electricity Rules
ROCOF	Rate of Change of Frequency
SYTS	Sydenham Terminal Station
TRTS	Tarrone Terminal Station

Contents

1 Introduction

This report reviews a power system operating incident that occurred on 4 July 2013 in Victoria. AEMO is required to review this incident as it is classified as a non-credible contingency that satisfies the requirements of a reviewable operating incident under the National Electricity Rules[1] (NER).

The purpose of this incident review is to assess power system security over the course of the incident. The NER requires AEMO 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].

This report is based upon information provided by AEMO[3], SP AusNet[4], and Pacific Hydro. Data from AEMO's Energy Management System (EMS) and Electricity Market Management System (EMMS) has also been used in analysing the incident.

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

2 The Incident

The Alcoa Portland (APD) – Heywood Terminal Station (HYTS) – Tarrone Terminal Station (TRTS) No.1 500 kV transmission line tripped out of service at 1451 hrs on 4 July 2013. The line tripped due to a single phase ground fault[5] on the Alcoa to Heywood section of the transmission line.

The fault occurred during high wind conditions near a tower where a live circuit transitioned to a bypass structure as part of project work. An out of service pre-made bridge conductor on the dead side of the tower came free from its lashing, due to the high winds, then came within arcing distance of a live conductor on the bypass structure. The protection that tripped the line operated correctly.

The following events also occurred concurrently:

- The Moorabool Terminal Station (MLTS) – TRTS No.1 500 kV transmission line tripped.
- Macarthur Wind Farm was islanded and reduced generation from 345 MW to 0 MW.
- Portland Wind Farm reduced generation from 98 MW to 0 MW.

These three events were not expected for a fault on the Alcoa to Heywood section of the transmission line.

3 Participant Investigations

AEMO and SP AusNet investigated the unexpected trip of the MLTS-TRTS No.1 500 kV transmission line. The investigation found that the circuit breaker fail function of the Anti-Resonance Protection Scheme[6] (ARPS) on the APD-HYTS-TRTS No.1 500 kV transmission line had operated.

The circuit breaker fail trip was caused by a higher than expected induced voltage on the disconnected phase of the APD-HYTS-TRTS No.1 500 kV transmission line. This resulted in the disconnection of the MLTS-TRTS No.1 500 kV transmission line and the islanding of Macarthur Wind Farm.

[1] *NER* v57 Clause 4.8.15(a)(1)(i) and AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.
[2] *NER* v57 Clause 4.8.15 (b)
[3] In Victoria AEMO is both the National Electricity Market operator and the Victorian Transmission Network Service Provider.
[4] Information provided by SP AusNet 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 SP AusNet (or its respective companies, businesses, directors, officers or employees).
[5] White phase fault to ground.
[6] See Appendix 1 for brief overview of the ARPS.

Pacific Hydro investigated the reduction in generation at Portland Wind Farm. Pacific Hydro found that rate-of-change-of-frequency (ROCOF) protection relays had operated when Macarthur Wind Farm tripped. This operation disconnected the Portland Wind Farm 22 kV collector cables, and thereby the wind farm, from the power system.

4 Pre-Contingent System Conditions

The status of the power system prior to the incident is shown in Figure 1. For clarity only equipment relevant to this incident has been included in the diagram. The diagram shows all 500 kV lines and equipment is service except for one circuit breaker at Moorabool Terminal Station which was out of service for a planned outage.

5 Summary of Events

The earth fault on APD-HYTS-TRTS No.1 500 kV transmission line was cleared correctly by differential protection. This protection operated in single phase automatic reclose (SPAR) mode on the faulted white phase as intended.

The ARPS then correctly operated (after a set delay of 1000ms) and opened circuit breaker 214 at Heywood Terminal Station. This action divided the disconnected line conductor into two sections to prevent a resonant circuit from forming. The induced voltage on these line sections was expected to be less than 30 kV (the protection setting). The induced voltage was however 50 kV.

The circuit breaker fail detection function of the ARPS was then triggered by this higher than expected voltage. The circuit breaker fail function then correctly tripped the MLTS-TRTS No.1 500 kV transmission line and the APD-HYTS-TRTS No.1 500 kV line, and reclosed circuit breaker 214 at Tarrone Terminal Station. The intent of this function is to increase the capacitance of the disconnected line to prevent a resonant circuit forming.

Macathur Wind Farm was then disconnected (islanded) due to the trip of the MLTS-TRTS No.1 500 kV transmission line.

Portland wind Farm was also disconnected due to the operation of ROCOF protection at the Portland Wind Farm 66/22 kV substation.

The sequence of events is summarised in Table 1. The status of the power system immediately after the incident is shown in Figure 2. The diagram shows, in green, open circuit breakers and the lines and plant that were disconnected.

Table 1: Summary of events during the incident

Time	Event
1451 hrs 4 July 2013	Single phase to ground fault on APD-HYTS-TRTS No.1 500 kV transmission line, protection operates on single phase as intended to clear fault.
1451 hrs 4 July 2013	ARPS on APD-HYTS-TRTS No.1 500 kV transmission line operates (after a set delay of 1000mS) and opens circuit breaker 214 at Heywood Terminal Station
1451 hrs 4 July 2013	Circuit breaker fail function of ARPS on APD-HYTS-TRTS No.1 500 kV transmission line operates. APD-HYTS-TRTS No.1 500 kV transmission line and MLTS-TRTS No.1 500 kV transmission line are tripped out of service.
1451 hrs 4 July 2013	500 kV circuit breaker 214 at Tarrone Terminal Station closes.
1451 hrs 4 July 2013	Macarthur Wind Farm reduced generation from 345 MW to 0 MW.
1451 hrs 4 July 2013	Portland Wind Farm reduced generation from 98 MW to 0 MW.

Figure 1: Status of the power system prior to the incident

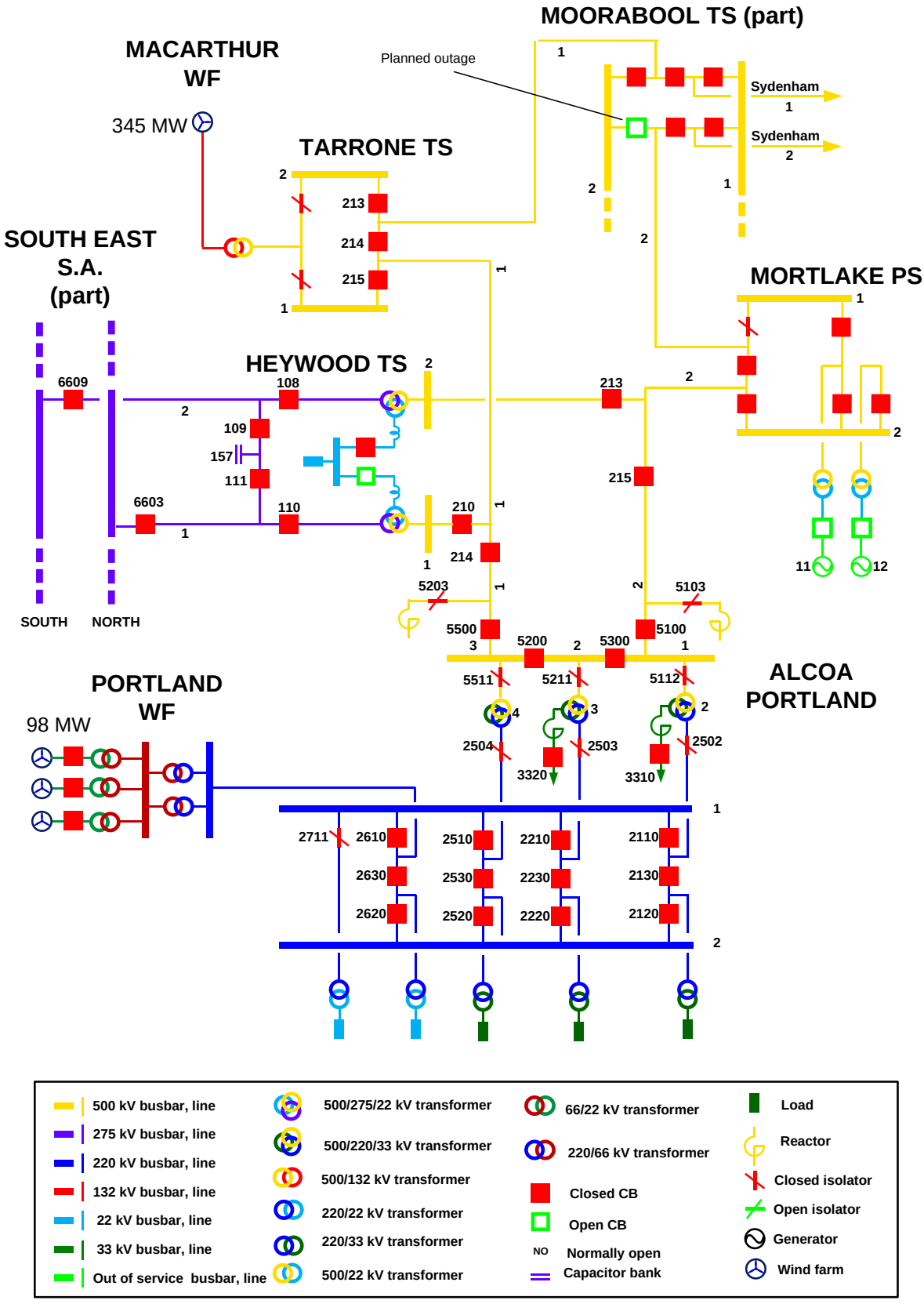
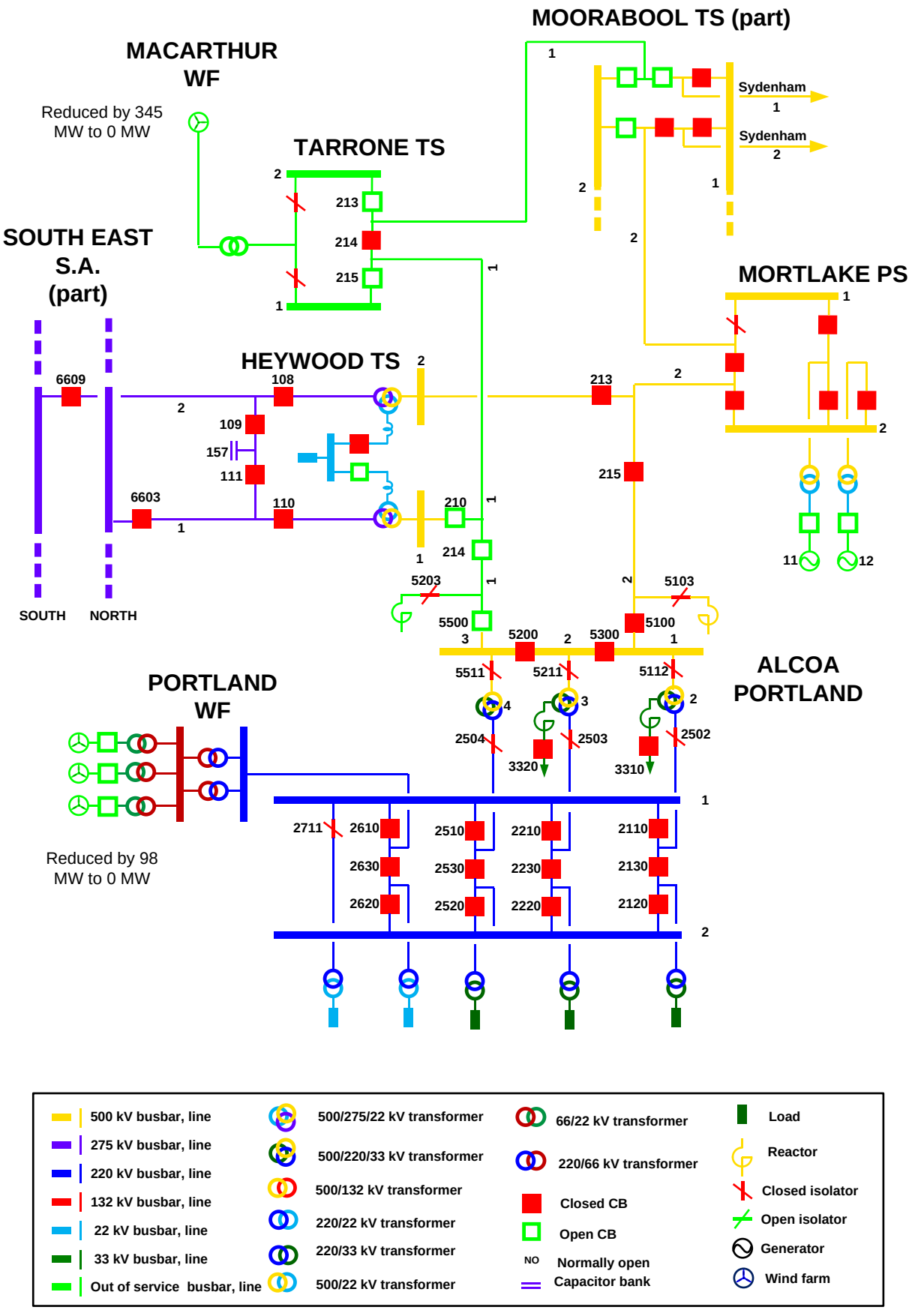


Figure 2 - Status of the power system immediately after the incident



6 Immediate Actions

At 1458 hrs - Portland Wind Farm was returned to service, eight minutes after the initial event.

AEMO invoked constraint sets V-HYTR[7], F-V-HYTR[8] and F-V-APHY_ONE[9] in DI ending 1500 hrs, and constraint sets V-MLTR[10] and V-MACARTHUR_ZERO[11] in DI ending 1505 hrs. These actions ensured that the power system was in a secure operating state. AEMO is required to return the power system to a secure state within thirty minutes following a contingency event.[12]

At 1514 hrs AEMO issued Market Notice 42807 – 23 minutes after the event - to notify the market that a non-credible contingency event had occurred. AEMO is required to notify the market of a non-credible contingency event within two hours of the event[13].

At 1521 hrs AEMO issued Market Notice 42808 to notify the market that South Australia may enter a Lack of Reserve 2 (LOR2)[14] condition.

At 1545 hrs AEMO recalled the planned outage of a circuit breaker at Moorabool Terminal Station (Bus 2 – MOPS No.2 line 500 kV circuit breaker). This circuit breaker was closed at 1545 hrs. This action prevented the possible separation of the Victorian and South Australian regions following the loss of the MLTS-Sydenham (SYTS) No.2 500 kV transmission line.

Between 1500 hrs to 1650 hrs the flow on the Heywood interconnector increased from approximately 50 MW to approximately 120 MW towards South Australia. As a consequence, from 1650 hrs South Australia entered an actual LOR2 condition.

At 1659 hrs AEMO issued Market Notice 42809 to notify the market of the LOR2 condition in SA. AEMO is required to notify the market as soon as reasonably practical when declaring a Lack of Reserve condition[15]. During this period the loss of the APD-HYTS-MOPS No.2 500 kV transmission line or MLTS-MOPS No.2 500 kV transmission line may have resulted in involuntary load shedding in South Australia[16].

At 1717 hrs APD-HYTS-TRTS No.1 500 kV transmission line and TRTS-MLTS No.1 500 kV transmission line were returned to service. SP AusNet had patrolled the APD-HYTS-TRTS No.1 500 kV transmission line and found that, during high winds, an out of service bridge conductor came free from its lashing and came within the arcing distance of a live conductor. SP AusNet secured the out of service bridge conductor to prevent the fault from reoccurring.

At 1734 hrs AEMO revoked all constraint sets that were invoked after the contingency, and cancelled the LOR2 condition in South Australia. AEMO issued Market Notice 42810 to notify the market that the LOR2 condition had been cancelled. AEMO is required to notify the market as soon as reasonably practical when cancelling and LOR declaration[17].

At 1813 hrs Macarthur Wind Farm returned to service.

At 1813 hrs AEMO issued Market Notice 42811 to notify the market the incident was not a non-credible contingency event; that is, AEMO considered the incident had always been reasonably possible and normal

[7] Out = Heywood to Tarrone No.1 500 kV line
[8] Out = Heywood to Tarrone No.1 500 kV line – FCAS requirements
[9] Out = Heywood to Alcoa Portland 500 kV line, Dynamic FCAS Lower Requirements for loss of the remaining 500 kV line
[10] Out = Moorabool to Tarrone No.1 500 kV line
[11] Macarthur Wind Farm upper limit of 0 MW
[12] *NER* v57 Clause 4.2.6 (b)
[13] AEMO, *Power System Security Guidelines,* v56 Section 10.3
[14] An LOR2 condition is a situation where AEMO considers that a credible contingency event may result in involuntary load shedding.
[15] *NER* v57 Clause 4.8.5(a)
[16] There were sufficient capacity reserves in South Australia to meet demand. However it may not have been possible to bring the required capacity into service in time to avoid involuntary load shedding.
[17] *NER* v57 Clause 4.8.5(c)(1)

and thereby a normal credible contingency. This action revised the previous advice in Market Notice 42807 that the event was a non-credible contingency. AEMO formed this opinion based on advice from SP AusNet that the ARPS had correctly operated and therefore a reoccurrence of the incident was normal and reasonably possible. At this stage, AEMO operating personnel were aware of the main functionality of the ARPS but not the circuit breaker fail function.

At 2026 hrs AEMO issued Market Notice 42812 to inform the market that AEMO now considered that the incident was not a normal credible contingency. AEMO reclassified the trip of APD-HYTS-TRTS No.1 500 kV transmission line, MLTS-TRTS No.1 500 kV transmission line, Macarthur Wind Farm and Portland Wind Farm as a credible contingency. AEMO operating personnel formed this opinion after reviewing the ARPS documentation. The documentation indicated that the circuit breaker fail function of the ARPS had operated which suggested that the 500 kV circuit breaker 214 at Heywood Terminal Station failed to open correctly[18].

The above assessments (Market Notices 42811 and 42812) are required by the NER. AEMO is required to assess whether or not to reclassify a non credible contingency event as a credible contingency[19] and to report how re-classification criteria were applied[20]. For both assessments AEMO correctly evaluated the abnormal conditions in accordance with the information at hand. Furthermore AEMO updated its assessment as new information came to hand.

The sequence of immediate actions is summarised in Table 2.

Table 2: Summary of immediate actions

Time	Event
1458 hrs 4 July 2013	Portland Wind Farm returns to service.
1500 hrs 4 July 2013	Constraint sets V-HYTR, F-V-HYTR, F-V-APHY_ONE invoked (during DI ending 1500 hrs).
1505 hrs 4 July 2013	Constraint sets V-MLTR, V-MACARTHUR_ONE invoked (during DI ending 1505 hrs)
1514 hrs 4 July 2013	Market Notice 42807 issued - for non-credible contingency event.
1521 hrs 4 July 2013	Market Notice 42808 issued - forecast LOR2 condition in South Australia region.
1545 hrs 4 July 2013	Bus 2 - MLTS-MOPS No.2 line 500 kV CB at MLTS closed.
1659 hrs 4 July 2013	Market Notice 42809 issued - actual LOR2 condition in South Australia region.
1717 hrs 4 July 2013	APD-HYTS-TRTS No.1 500 kV transmission line and MLTS-TRTS No.1 500 kV transmission line returned to service.
1730 hrs 4 July 2013	Constraints sets V-HYTR, F-V-HYTR, F-V-APHY_ONE,V-MLTR-V-MACARTHUR_ONE revoked.
1734 hrs 4 July 2013	Market Notice 42810 issued - LOR2 condition in South Australia region cancelled.
1813 hrs 4 July 2013	Macarthur Wind Farm returns to service.
1813 hrs 4 July 2013	Market Notice 42811 issued - revision to Market Notice 42807; incident determined to have always been reasonably possible and is *not* a non-credible contingency event.
2026 hrs 4 July 2013	Market Notice 42812 issued - incident reclassified as a credible contingency.

[18] The 500 kV circuit breaker 214 at Heywood Terminal Station was later determined to have opened correctly.
[19] *NER* v57 Clause 4.2.3A (c)
[20] *NER* v57 Clause 4.8.15 (ca)

7 Follow-up Actions

The incident was investigated over the following 24 hours by AEMO and SP AusNet. Inspection of high speed measurements showed that:

1. The fault on the white phase of the APD-HYTS No.1 500 kV transmission line was correctly cleared via SPAR protection as intended.
2. After the white phase opened, the induced voltage on the isolated white phase was approximately 50 kV.

The circuit breaker fail function of the ARPS was set to trigger after a 1000 millisecond time delay if the induced voltage on the isolated phase exceeded 30 kV. AEMO concluded that the 30 kV setting was appropriate for three phase isolation of the line, but not single phase isolation. On 5 July 2013 the SPAR mode on the APD-HYTS-TRTS No.1 500 kV transmission line was disabled while AEMO determined more appropriate protection settings.

After the SPAR mode had been disabled, AEMO issued Market Notice 42819 at 1841 hrs on 5 July. This notified the market that the contingency event reclassification declared in Market Notice 42812 was revised to include only APD-HYTS-TRTS No.1 500 kV transmission line and Portland Wind Farm.

Pacific Hydro investigated the reduction in generation at Portland Wind Farm. The reduction was caused by the operation of anti-islanding ROCOF protection relays at the wind farm 66/22 kV substations. This operation isolated the 22 kV wind farm collector cables from the power system. Pacific Hydro advised AEMO that the ROCOF relays would be removed from service, and that protection on the individual wind turbines would be suitable for an islanding event.

Pacific Hydro removed the ROCOF relays by 6 August 2013. On 7 August 2013, AEMO issued Market Notice 43015 advising the market that the reclassification of APD-HYTS-TRTS No.1 500 kV transmission line and Portland Wind Farm as a credible contingency had been cancelled.

AEMO completed its review of the ARPS protection settings by 7 August 2013. AEMO then requested that SP AusNet implement new voltage threshold and time delay settings in the ARPS.

8 Power System Security Assessment

AEMO is responsible for power system security in the NEM and is required to operate the power system in a secure operating state[21]. AEMO must thereby ensure that the power system is maintained in, or returned to, a secure operating state following a contingency event.

For the duration of the incident power system voltages and frequencies remained within the normal operating bands and the power system remained in a secure operating state. The provision and response of facilities and services were adequate to maintain power system security.

The South Australia region was in an actual LOR2 condition from 1650 hrs 4 July 2013 until 1730 hrs 4 July 2013. During this time the loss of APD-HYTS-MOPS No.2 500 kV transmission line or MLTS-MOPS No.2 500 kV transmission line may have resulted in involuntary load shedding in South Australia.

The protection settings originally issued by AEMO for the ARPS were not appropriate for single phase isolation of the APD-HYTS-TRTS No.1 500 kV transmission line.

AEMO had documented the main ARPS functions in its operating procedures when it was commissioned with Tarrone Terminal Station in 2012. The circuit breaker fail function of the ARPS was not documented in AEMO's procedures. AEMO operating personnel only became aware of the ARPS circuit breaker fail function when it had actually operated.

[21] *NER* v57 Clause 4.2.4 (a)

9 Conclusions

This incident that occurred in Victoria at 1451 hrs 4 July 2013 was initiated by a single phase to ground fault on the APD-HYTS-TRT1 No.1 500 kV line, and aggravated by inappropriate protection settings of the ARPS on the APD-HYTS-TRTS No.1 500 kV transmission line.

AEMO is satisfied that appropriate measures have been taken to mitigate the risk of a similar incident reoccurring in the future. That is, the SPAR mode on the APD-HYTS-TRTS No. 1 500 kV transmission line has been disabled until revised ARPS protection settings are applied.

AEMO correctly applied the criteria published in Section 11 of its Power System Security Guidelines in assessing that the circumstances of this incident warranted reclassifying this incident as a credible contingency event.

10 Recommendations

1. AEMO to review, and if necessary amend, its processes to ensure that new protection settings issued by AEMO are appropriate. To be complete by 29 November 2013.
2. AEMO to review, and if necessary amend, its processes to ensure that new control schemes are correctly documented in AEMO's operational procedures. To be complete by 31 October 2013.
3. SP AusNet to implement new protection settings in the ARPS - issued by AEMO on 7 August 2013. To be completed by 31 October 2013.

Appendix 1 – Overview of Anti-Resonance Protection Scheme

The ARPS is designed to prevent high voltages being induced on a disconnected line conductor(s) on the APD-HYTS-TRTS No. 1 500 kV transmission line.

A high induced voltage on the disconnected line (whether isolated in one phase or all phases) is caused by a 50 Hz resonant circuit formed by:

- Capacitive coupling with the APD-HYTS-MOPS No.2 500 kV transmission line, and
- The inductance of the APD-HYTS-TRTS No.1 500 kV transmission line reactor located at Alcoa Portland.

The ARPS is designed to open 500 kV circuit breaker 214 at Heywood Terminal Station and divide the disconnected line into two sections. This dividing of the conductor reduces capacitance and prevents a resonant circuit from forming. Circuit breaker 214 is not used to clear a fault on APD-HYTS-TRTS No.1 500 kV transmission line.

Should circuit breaker 214 at Heywood Terminal Station fail to open, the circuit breaker fail function of the ARPS operates. The circuit breaker fail function disconnects the APD-HYTS-TRTS No.1 500 kV line and the MLTS-TRTS No.1 500 kV transmission line, and then closes the circuit breaker 214 at Tarrone Terminal Station. This creates a single isolated APD-HYTS-TRTS-MLTS 500 kV line, which increases the capacitance of the disconnected line and prevents a resonant circuit from forming.

In this incident the circuit breaker fail function was triggered by an induced voltage setting of greater than 30 kV phase to ground after a pre-set delay of 1000ms.