Power System Operating Incident Report – Trip of Ringwood-Rowville 220 kV Transmission Line and Multiple Generators on 29 September 2013

PREPARED BY: AEMO Systems Capability

DATE: 27 December 2013

FINAL

Contents

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Version Release History

VERSION	DATE	BY	CHANGES	CHECKED BY	AUTHORISED BY
1	27 Dec 2013	J Duque	Final	S Darnell	P Biddle

Incident Classifications

Time and date and of incident	1139 hrs Sunday 29 September 2013
Region of incident	Victoria
Affected regions	Victoria and Tasmania
Event type	TG – Loss of transmission elements and generating units
Primary cause	TE - Transmission equipment failure
Impact	Very Significant
Associated reports	Nil

Abbreviations and Symbols

Abbreviation	Term
AEMO	Australian Energy Market Operator
CB	Circuit Breaker
EMMS	Electricity Market Management System
EMS	Energy Management System
GPS	Generator Performance Standards
kV	Kilovolt
MW	Megawatt
NER	National Electricity Rules
WF	Wind Farm

1 Introduction

This report reviews a power system operating incident that occurred on 29 September 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], Powercor, Energy Australia, Hydro Tasmania and AGL. 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

On Sunday 29 September 2013, at 1139 hrs, the Ringwood - Rowville 220 kV transmission line tripped, auto reclosed and then tripped again. This trip-close-trip event caused a significant power system disturbance.

As a result of the power system disturbance Yallourn Power Station Unit 1 and Oaklands Hill Wind Farm tripped from 310 MW and 51 MW respectively, and Macarthur and Musselroe[5] Wind Farms reduced generation by 48 MW and 26 MW respectively. Also, load reduced by approximately 100 MW in the Victorian region.

The primary reason for investigating this incident is that several generating units tripped as a result of a power system fault. Generally for a power system fault, generating units are required to remain connected to the power system whilst protection systems react and clear the fault.

3 Incident Investigations

The incident was investigated by the entities affected by the fault. This section summarises the findings of those investigations.

3.1 Transmission Network - SP AusNet

The Ringwood - Rowville 220 kV transmission line tripped, auto reclosed, tripped again, and then locked out. The two trips were due a bridge connection failure on a tower close to Rowville Terminal Station (Tower No. 2)

The bridge connection failure initially caused a phase to earth fault that was correctly cleared by protection. Then, via an auto-reclose, the bridge connection caused a phase-to-phase fault which was again correctly cleared by protection.

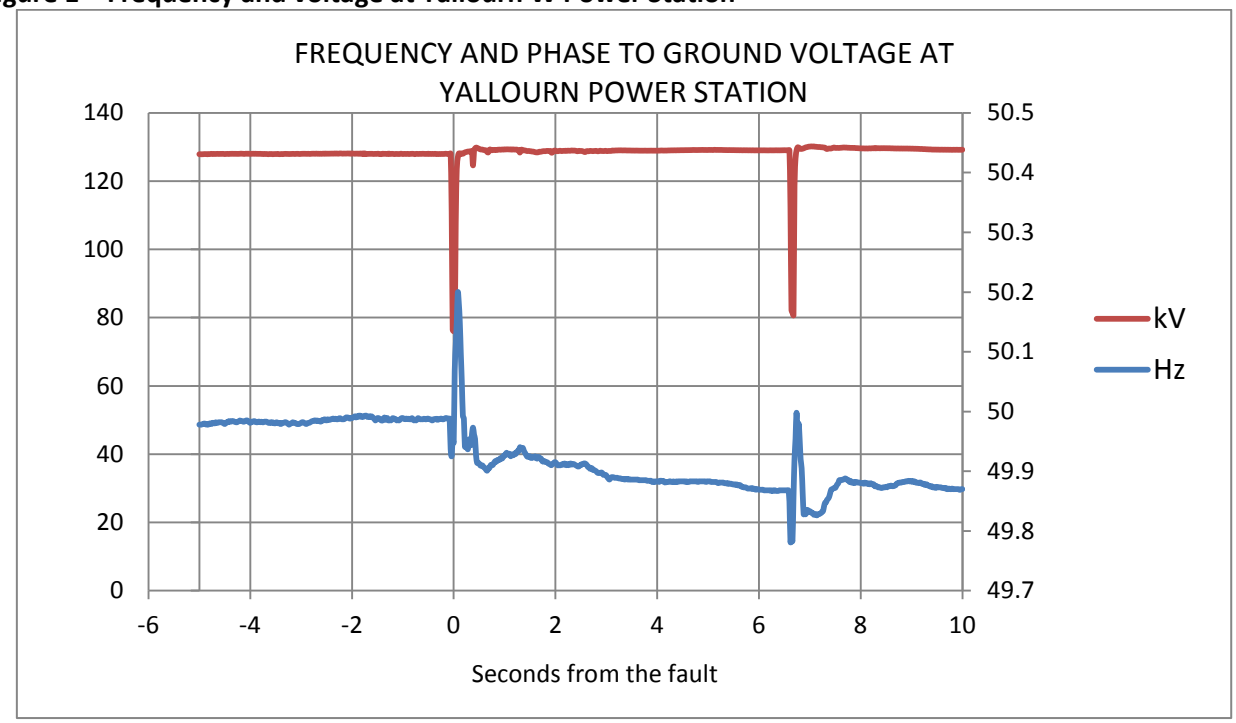
[1] *NER* v57 Clause 4.8.15(a)(1)(i) and AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.
[2] *NER* v57 Clause 4.8.15 (b)
[3] In Victoria AEMO is both the National Electricity Market operator and the Victorian Transmission Network Service Provider.
[4] Information provided 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 associated companies, businesses, partners, directors, officers or employees).
5 AEMO became aware of this reduction of generation at Musselroe WF on the 3 November, after further analysis of the event.

The first trip was a blue phase to earth fault. Current differential protection (both X and Y) operated at Rowville Terminal Station and Ringwood Terminal Station to clear the fault. This was followed by an auto reclose at Rowville Terminal Station which reclosed onto a white to blue phase fault. Current differential protection (both X and Y) operated at Rowville Terminal Station to clear the fault. Ringwood Terminal Station is the synchronous check end and hence did not attempt to auto reclose. The line fault clearance times were within the NER requirements[6].

The bridge connection was repaired and the line was restored into service on the same day at 2355 hrs.

Figure 1 shows the voltage and frequency disturbances caused by the two faults - measured on the 220 kV system at Yallourn Power Station. The graph shows frequency (blue) and average phase to ground voltage (red). The voltage fell to a low of 76.4 kV_{Ph-G} for the first fault and to 81.56 kV_{Ph-G} for the second fault. The frequency remained within operational bands during the two events.

Figure 1 – Frequency and voltage at Yallourn W Power Station



3.2 Yallourn Power Station - EnergyAustralia

Yallourn Power Station Unit 1 tripped due to low generator terminal voltage. This trip was unexpected for the type of fault that triggered this incident.

The terminal voltage fell from 20 kV to 18.7 kV. This low generator terminal voltage, and the high rate of change of the voltage depression (dU/dt >-500%/s), caused the Automatic Voltage Regulator to trip to manual and in turn trip the unit. Energy Australia then declared Yallourn Unit 1 as not compliant with its Performance Standard and scheduled to implement a solution during a planned outage in April 2014. This

[6] NER fault clearance time requirement is 120ms for near-end faults, and 220ms for remote-end faults for system with nominal voltage between 100kV and 250kV. The initial fault was cleared in 82ms at Rowville Terminal Station and 150ms Ringwood Terminal Station. The second fault following the reclose was cleared in 73 ms at Rowville Terminal Station.

arrangement was later modified (see Section 8 of this report) and the non-compliance was rectified in early December 2013.

3.3 Oaklands Hill Wind Farm - AGL

Oaklands Hill Wind Farm tripped from 51 MW at the same time of the transmission event. An overvoltage on the distribution network tripped the incoming 66 kV CB at the wind farm. AGL declared Oakland Hill Wind Farm non-compliant with its generator performance standard (GPS).

Powercor have been unable to identify the source of the overvoltage on the distribution network and its relationship to the fault on the transmission network.

AGL and Powercor are considering a longer time delay on overvoltage protection before tripping Oaklands Hill Wind Farm. This would allow short duration transient over voltages to pass before a trip is triggered. AGL, in conjunction with Powercor, expect to implement a solution by 31 March 2014.

The response of the static compensator[7] (STATCOM) at Oaklands Hill Wind Farm AGL is also being investigated by AGL and the STATCOM manufacturer. AGL considers that the overvoltage was of such a short duration that the STATCOM possibly did not have time to respond.

AGL is also investigating the level of harmonics and voltage unbalance at the 66 kV connection point. AGL considers that transient over-voltage events may be undetected by the STATCOM and therefore not damped because the STATCOM controls are based on a filtered voltage signal.

AGL expect to complete their STATCOM investigations by 31 March 2014.

3.4 Macarthur Wind Farm - AGL

At Macarthur Wind Farm sixteen turbines tripped due the transmission system disturbance. The turbine trips were unexpected for the type of fault that triggered this incident. AGL declared Macarthur Wind Farm non-compliant with its GPS.

The turbines tripped on frequency error. The exact cause of this frequency error remains unknown. The turbines were returned to service approximately five minutes after they tripped. AGL are investigating this event and expect to implement a solution by 31 March 2014.

3.5 Musselroe Wind Farm – Hydro Tasmania

At Musselroe Wind Farm in Tasmania eight wind turbines tripped as result of the transmission disturbance in Victoria. The turbine trips were not expected for the type of fault that triggered this incident. The turbines were returned to service at approximately 1145 hrs on 29 September.

Those eight turbines are part of a group of 11 turbines that have faults initially identified during testing in September 2013. The faults are related to hardware, software and inappropriate protections settings.

On 16 October 2013, after further investigations of similar events, Hydro Tasmania declared eleven turbines at Musselroe Wind Farm non-compliant with their GPS (including the eight that tripped on 29 September). The faults associated with five of those turbines were rectified and the turbines remained in service. The remaining six turbines were removed from service on 31 October 2013 as requested by AEMO and Transend. Following corrective action the turbines were incrementally returned to service. AEMO subsequently closed the non-compliance on 05 November 2013.

On 03 December 2013, Hydro Tasmania informed AEMO that some of the affected turbines continued to exhibit similar problems. AEMO subsequently reopened the non-compliance for wind turbines at Musselroe

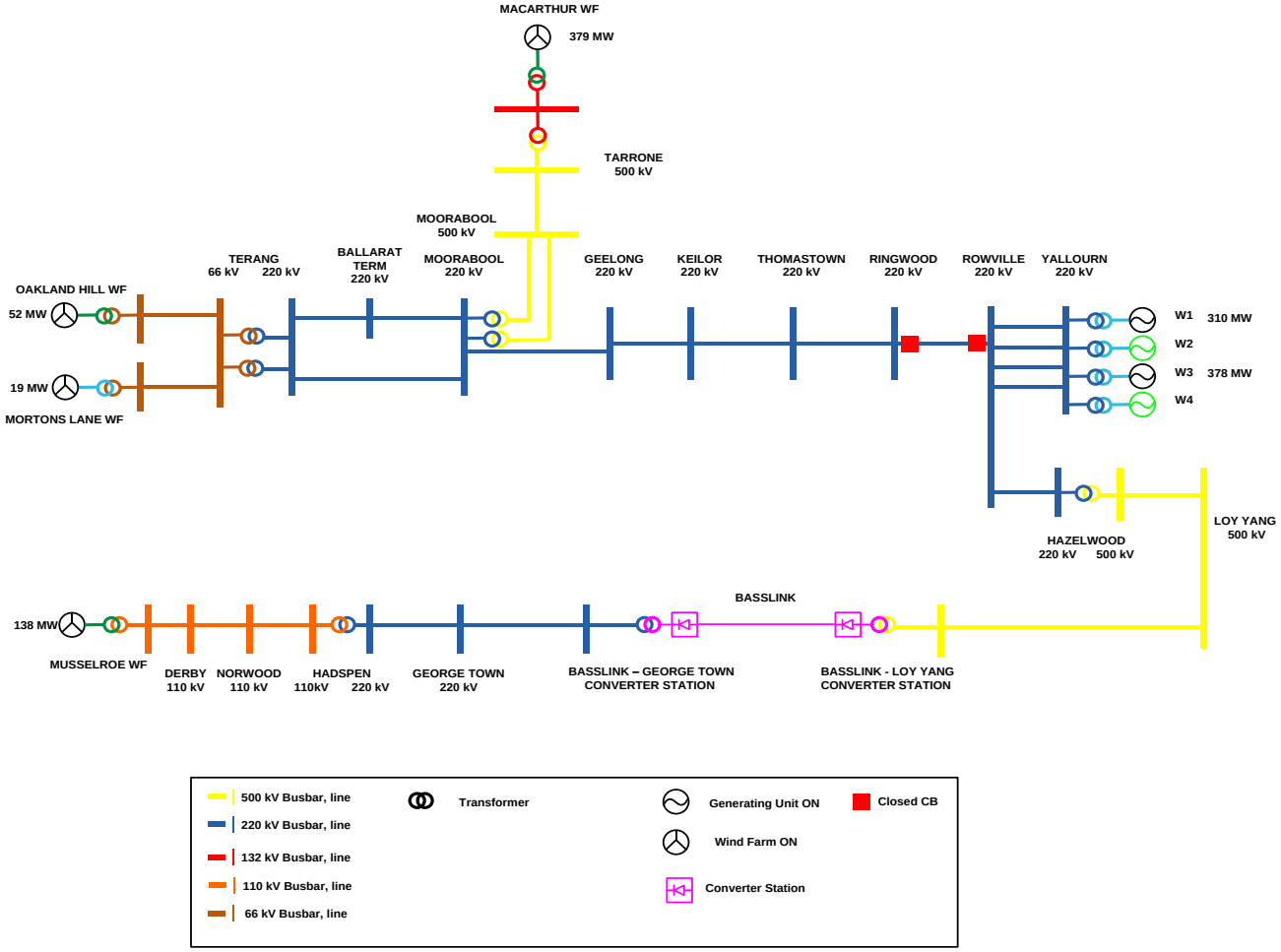
[7] A static compensator is a device used to manage voltage via use of reactive power.

Wind Farm. The non-compliance was then closed on 11 December 2013 when Hydro Tasmania notified AEMO that the non-conformance at Musselroe Wind Farm had been rectified.

4 Power System Pre-Incident State

The status of the power system prior to the incident is shown in Figure 2. For clarity only equipment relevant to this incident has been included in the diagram. The diagram shows the interconnected sections of the Victoria and Tasmania networks where the affected plant is located.

Figure 2 - Status of the power system prior to the incident



5 Incident Event Log

The sequence of events comprising the incident are itemised in Table 1.

Table 1 – Event Log

Time and Date	Event
11:39 29 Sept 2013	Ringwood - Rowville 220 kV Transmission Line tripped, auto reclosed and reopened.
	Oaklands Hill WF tripped from 51 MW
	Yallourn Unit 1 tripped from 310 MW
	Macarthur WF reduced generation by 48 MW (several turbines tripped)
	Musselroe WF reduced generation by 26 MW (several turbines tripped)

	Load reduced by approximately 100 MW in Victoria due to voltage disturbance
14:41 29 Sept 2013	Oaklands Hill WF returned to service
15:39 29 Sept 2013	Market Notice 43447 issued notifying the market of a non-credible contingency
19:11 29 Sept 2013	Yallourn Unit 1 returned to service
23:48 29 Sept 2013	SP AusNet notified AEMO that protection operated correctly at both Ringwood and Rowville. The clearing times were within the requirements for primary protection.
23:55 29 Sept 2013	Ringwood - Rowville 220 kV transmission line returned to service
00:14 30 Sept 2013	Market Notice 43455 issued notifying the market that the cause of the transmission fault was identified and rectified. AEMO thereby did not reclassify this event as a credible contingency event.
09:58 30 Sept 2013	Based on a further review of the information, AEMO modified its decision and issued Market Notice 43456 reclassifying the event as a credible contingency.

6 Power System Post-Incident State

The status of the power system immediately after the incident is shown in Figure 3. For clarity only equipment relevant to this incident has been included in the diagram. The diagram shows transmission line and generating units affected by the event.

7 Immediate Actions

No immediate action was required of AEMO. The power system was in a secure state following the initial events.

The turbines that tripped at Macarthur Wind Farm and Musselroe Wind Farm returned to service at approximately 1145 hrs on 29 September.

Oaklands Hill Wind Farm, Yallourn W Unit 1 and the Ringwood - Rowville 220 kV transmission line remained out of service for inspection.

8 Follow-up Actions

Oaklands Hill Wind Farm returned to service at 1441 hrs and Yallourn Unit 1 at 1911 hrs on 29 September 2013.

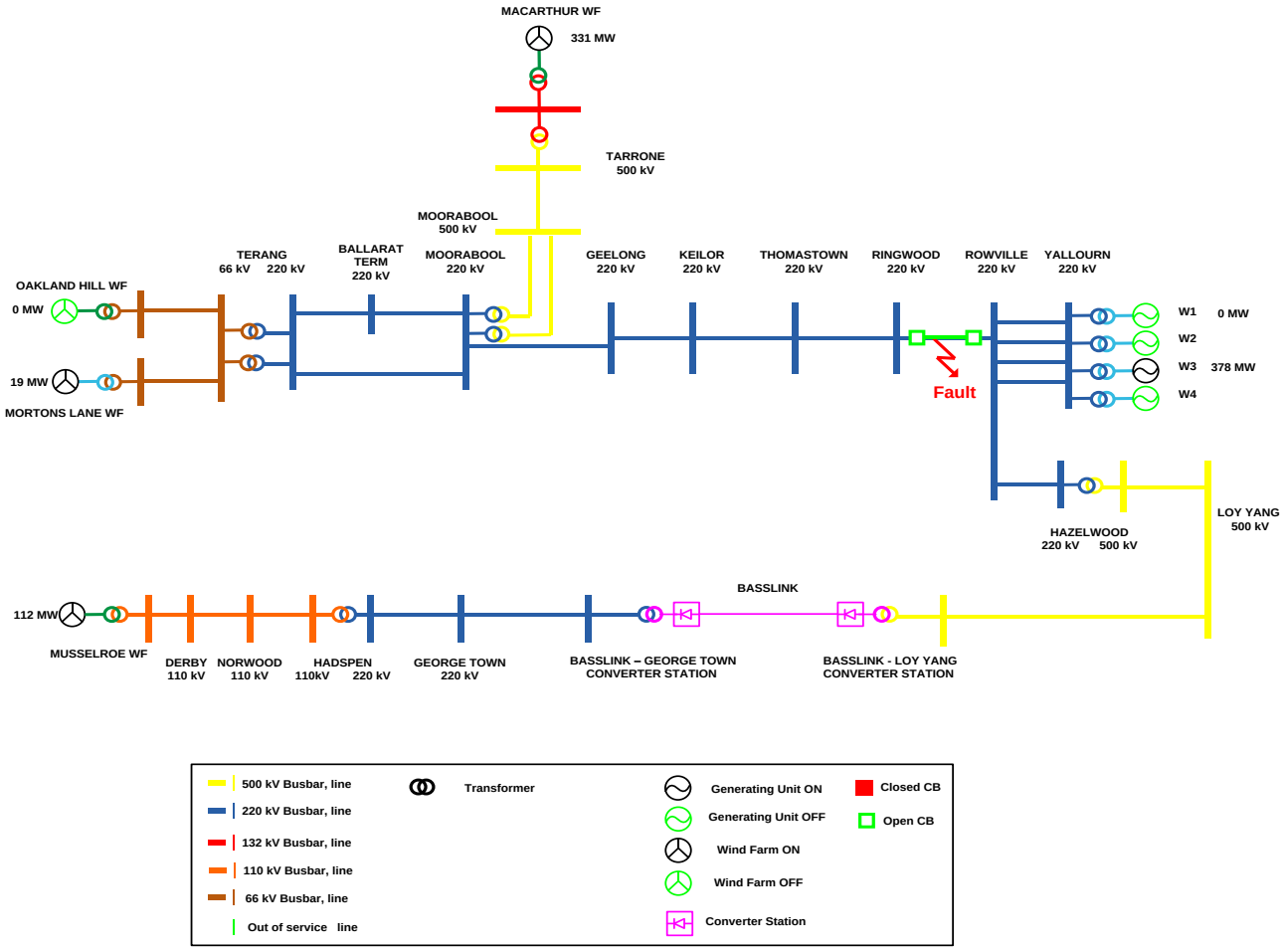
AEMO issued Market Notice 43447 at 1539 hrs on 29 September informing the market of the non-credible contingency (4 hours after the event). This notification was not within the two-hour period in which AEMO is required to notify the market of a non-credible contingency event[8]. AEMO has since reinforced the incident notification process to ensure information is passed onto the market in a timely manner.

SP AusNet repaired the bridge connection and returned the line to service at 2355 hrs.

AEMO issued Market Notice 43455 at 0014 hrs on 30 September 2013 to inform the market that the event would not be reclassified as a credible contingency. AEMO considered that the cause of the transmission event had been identified and protection had operated correctly.

[8] AEMO, *Power System Security Guidelines,* v54 Section 10.3

Figure 3 - Status of the power system immediately after the incident



Following further consideration of the same information, AEMO amended its initial reclassification decision. AEMO considered that although the cause of the transmission fault had been rectified the cause of the generator trips had not yet been identified and rectified. AEMO reclassified the simultaneous loss the Ringwood - Rowville 220kV transmission line, Yallourn Unit 1, Oakland Hill Wind Farm, and reduced generation at Macarthur Wind Farm as a credible contingency. AEMO issued Market Notice 43456 at 0958 hrs on 30 September 2013 to notify the market of this reclassification.

At this time AEMO also considered that the impact of this contingency did not require any additional constraints to manage power system security. The major factor being that the sum of the generation included in this contingency is less than the single largest generating unit.

On 14 November 2013, in replying to an AEMO query regarding the response of Unit 3[9] during the fault, Energy Australia informed AEMO that the AVRs on Yallourn Unit 1 and Unit 3 were different; Unit 3 AVR had a longer trip delay for low voltage events. Energy Australia also informed AEMO that the AVRs on Yallourn Unit 1 and Unit 2 were the same. At this time AEMO did not further consider this information.

However, because the AVRs on Yallourn Units 1 and 2 are the same, this meant that for a power system fault close to Yallourn Unit 3 (or 4), the disturbance could trip Yallourn Units 1 and 2 in addition to Yallourn

[9] AEMO enquired why Yallourn Unit 3 did not trip as a result of the power system fault – Units 2 and 4 were out of service

Unit 3 (or 4). That is, up to three units at Yallourn Power Station (up to 1165 MW) was a credible contingency (Units 1, 2 and 3 or 4). AEMO did not identify this inherent scenario until early December.

On 10 December AEMO contacted EnergyAustralia to verify that the AVRs on Units 1 and 2 were configured the same, in particular the trip delay for low voltage events. EnergyAustralia confirmed that the AVRs were the same and thereby had the same risk of trip due to the shorter trip delay. After discussing the newly identified risks with AEMO, EnergyAustralia then arranged to modify the AVR trip delays on Yallourn Units 1 and 2. This work was complete by 13 December 2013.

As a result, from 21:00 hrs on 29 September 2013 to 12:30 hrs on 13 December 2013, the Power System may have been in an insecure operating state. This was due to the potential of up to three Yallourn Units to trip for a single fault (that is, for a power system fault close to Yallourn Unit 3 (or 4) resulting in the trip of Yallourn Units 1, 2 and 3 (or4)).

Subsequently the original event reclassification was amended to remove Yallourn units. The reclassification as of 27 December 2013 includes the trip or partial trip of Oaklands, Macarthur and Mortons Lane[10] wind farms for a 220 kV power system fault in Victoria.

9 Power System Security

The protection systems of the Ringwood – Rowville 220 kV transmission line operated correctly to clear both faults in accordance with the NER.

The trips at several power stations however revealed non-compliances with the performance standards - Yallourn Unit 1 and 2, and Oaklands Hill, Macarthur and Musselroe Wind Farms. All parties notified AEMO of their respective non-compliance as per Section 4.145 of the NER.

Remedial work at Musselroe Wind Farm and Yallourn units 1 and 2 were completed on 11 and 13 December 2013 respectively. Works at Oaklands Hill Wind Farm and Macarthur Wind Farm are expected to be complete by 30 April 2014

The reclassification of any 220kV transmission fault in Victoria plus the trip of Oaklands Hill Wind Farm, Mortons Lane Wind Farm and reduction of generation at Macarthur Wind Farm will remain in place until remedial work is complete.

Power System voltage and frequency remained within limits during this event.

The Power System may have been in an insecure for periods between 29 September 2013 and 13 December 2013. This was due to the possibility of losing up to three units at Yallourn Power Station for a single credible contingency as identified during the course of this investigation. Whether or not the system was secure would have been dependent upon the loading and the number of Yallourn Power Station units on line at a particular time. The potential consequences of such a contingency could have been frequency violations or voltage collapse in Victoria. The voltage collapse would have been unlikely however due to the relatively low demand during this period.

10 Conclusions

1. The trip of the Ringwood – Rowville 220 kV Transmission Line was due to a connection bridge failure which caused an initial single phase to ground fault, and then a phase to phase fault after auto reclose of the line. Both faults were correctly cleared.
2. The initial power system disturbance on the transmission system caused Yallourn Unit 1, and Oaklands Hill, Macarthur, and Musselroe Wind Farms to trip. These units failed to meet their

[10] Mortons Lane Wind Farm is now included in the reclassification as this wind farm tripped during a similar event on 13 October 2013. AEMO will also produce a Power System Incident Report for that event.

relevant performance standards by tripping under fault conditions. Later Yallourn unit 2 was also identified as non-complaint with its performance standards.

3. AEMO failed to issue a Market Notice advising on the occurrence of a non-credible contingency in a timely manner as required by AEMO's Power System Security Guidelines.
4. AEMO did not initially reclassify the multiple contingency event as credible contingency event. This decision was reversed on 30 September after further analysis and consideration of the available information.
5. The Power System may have been insecure between 21:00 hrs on 29 September 2013 and 12:30 hrs on 12 December 2013.

11 Pending Actions

1. AGL to inform AEMO of the outcomes of the investigation about the performance of the STATCOM at Oaklands Hill Wind Farm during this event. The information exchange will progress via the generator non-compliance process. The Investigation is expected to be completed by 31 March 2014.

2. AGL to inform AEMO of the outcome of their compliance assessment in regards to voltage unbalance and harmonic levels at Oaklands Hill Wind Farm connection point. The information exchange will progress via the generator non-compliance process. Assessment to be completed by 31 March 2014.

12 Recommendations

1. AEMO to investigate why a potential multiple unit contingency at Yallourn Power Station was not identified in a timelier manner following the original incident. AEMO will then and amend its procedures accordingly. This is to be completed by 31 January 2014.