POWER SYSTEM INCIDENT REPORT: OVERLOAD OF WAUBRA- HORSHAM 220 KV TRANSMISSION LINE AND INSECURE OPERATION OF THE SYSTEM ON 13 DECEMBER 2012

PREPARED BY: Systems Capability

VERSION: 1

DATE: 29 April 2013

FINAL

Disclaimer

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Abbreviations and Symbols

Abbreviation	Term
DI	Dispatch Interval
EMMS	Electricity Market Management System
EMS	Energy Management System
HVDC	High Voltage Direct Current
kV	Kilovolt
MVA	Mega Volt-Amp
MW	Megawatt
NER	National Electricity Rules
PCR	Protection and Control Requirement
RTCA	Real Time Contingency Analysis
RTNET	Real Time Network Analysis
SCADA	Supervisory Control and Data Acquisition System

Contents

Incident summary

Date and time of incident	13/12/2012 1442 hrs to 1457 hrs
Region of incident	VIC
Affected regions	VIC
Event type	OTH - Other
Primary cause	ENVI & OTHER – Environment and Other
Impact	Nil
Associated reports	Nil

1. Introduction

On 13 December 2012, two different but related events affected the normal operation of the power system:

- Due to unplanned outage of Robertstown – North West Bend No.1 132 kV Transmission Line coincident with an outage of the Darlington Pt – Balranald - Buronga ('X5 line') 220 kV Transmission Line, the power system was not in a secure operating state from 1228 hrs to 1300 hrs, for a total period of 32 minutes; and
- The loading on the Waubra – Horsham 220kV Transmission Line exceeded the continuous thermal rating of the line on two occasions between 1441 hrs to 1457 hrs, for a total duration of 11 minutes. The maximum loading was 425 MVA at 1452 hrs which exceeded the continuous rating of 308 MVA by 117 MVA.

This report has been prepared under clause 4.8.15 (c) of the National Electricity Rules (NER) 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.

This report is largely based upon Data from AEMO's Energy Management System (EMS) and Electricity Market Management System (EMMS) and information provided by SP AusNet[1].

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

2. Pre-Contingent System Conditions

The Darlington Pt – Balranald - Buronga ('X5 line') 220 kV Transmission Line was out of service from 1254 hrs on 12 December 2012 till 1647 hrs on 14 December 2012, to repair a fallen conductor of the line near Balranald Substation.

Constraint set N-BUDP was invoked for this outage. This set includes constraint equations that prevent post contingency overload on the Bendigo to Kerang, Horsham to Waubra, Kerang to Wemen and Ballarat to Bendigo 220kV Transmission Lines.

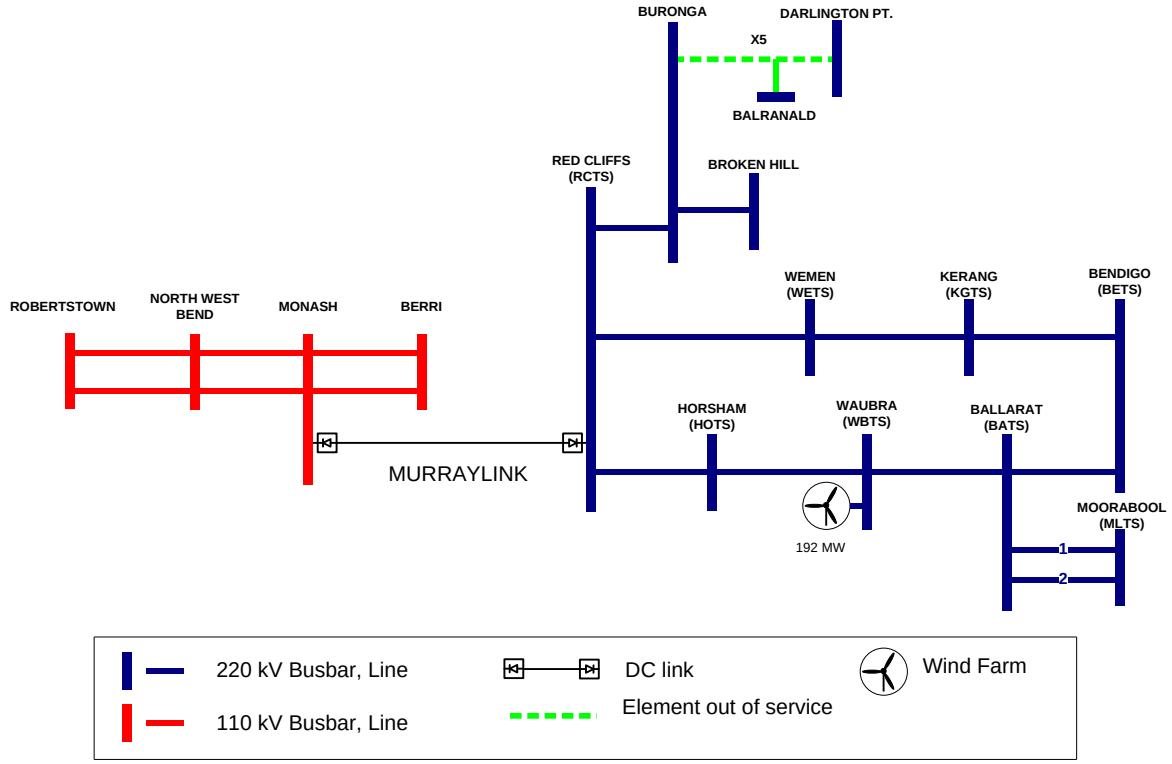
On 13 December, between 1200 hrs and 1230 hrs, these constraints for the outage of the X5 line required flow of approximately 80 MW from South Australia to Victoria on the High Voltage Direct Current (HVDC) interconnection ('Murraylink Interconnector'), to provide support to the Victoria outer state grid load. Further flow on the Murraylink Interconnector from South Australia to Victoria was limited by the loading on the Robertstown - Northwest Bend No.1 132 kV Transmission Line in South Australia.

Between the 12:10 and 12:30 Dispatch Intervals (DIs), the constraints for outage of the X5 line violated. This occurred as the X5 line outage constraints required further flow on the Murraylink Interconnector from South Australia to Victoria, however further flow on the Murraylink Interconnector was prevented due to the rating of the Robertstown - Northwest Bend No.1 132 kV Transmission Line.

The status of the power system prior to the incidents is shown in Figure 1. For clarity only equipment relevant to this incident has been included in the diagram.

[1] 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).

Figure 1 - Status of the power system prior to the incident, 1226 hrs 13 December 2012.

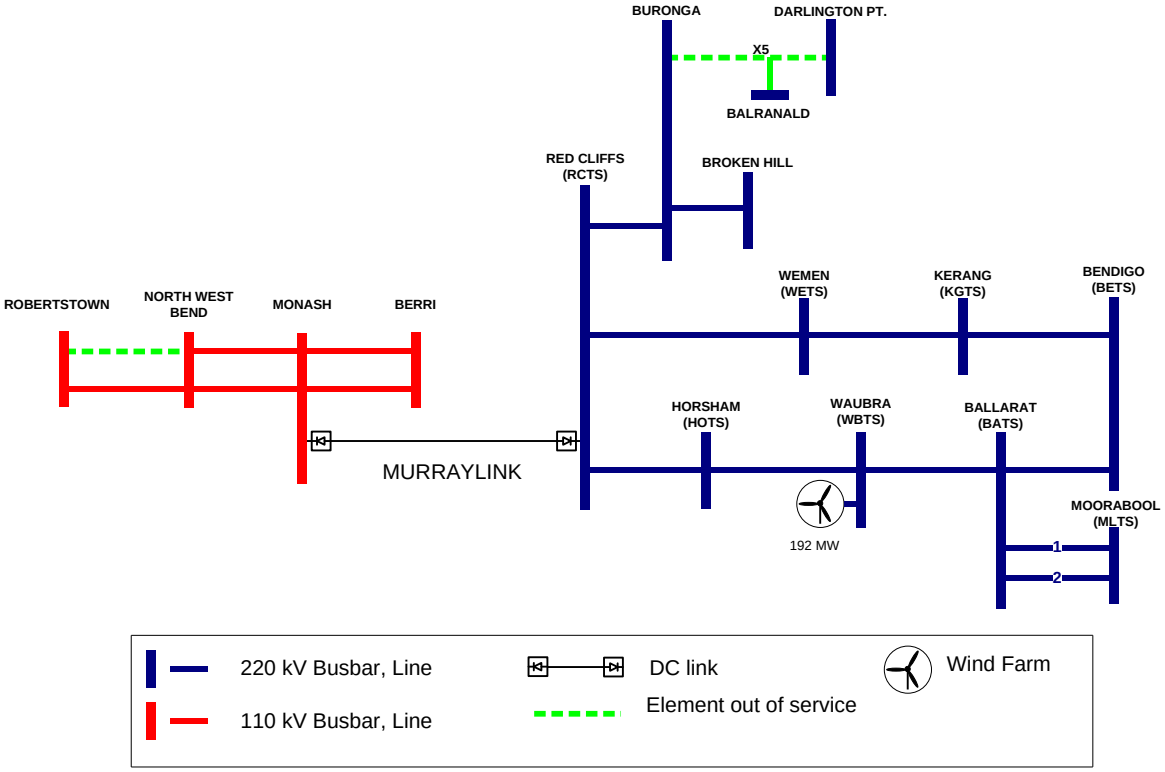


3. Summary of Incident

At 1227 hrs 13 December 2012, the Robertstown - North West Bend No.1 132 kV Transmission Line tripped out of service in the South Australia region. Lightning was observed in the area at the time.

The status of the power system after the Robertstown - North West Bend No.1 132 kV Transmission Line contingency is shown in Figure 2.

Figure 2 - Status of the power system after Robertstown- North West Bend contingency, 1227 hrs 13 December 2012.



Following the outage of the Robertstown - North West Bend No. 1 132 kV Transmission Line, the Murraylink Interconnector was unable to provide significant flow from South Australia to Victoria, however due to the ongoing outage of the X5 line, and very hot weather conditions and high demand in Victoria, significant flow on the Murraylink Interconnector was required from South Australia to Victoria. At this time, AEMO's Real Time Contingency Analysis (RTCA) system was indicating that a trip of the Bendigo–Kerang 220 kV Transmission Line would result in the overload of the Waubra-Horsham 220 kV Transmission Line.

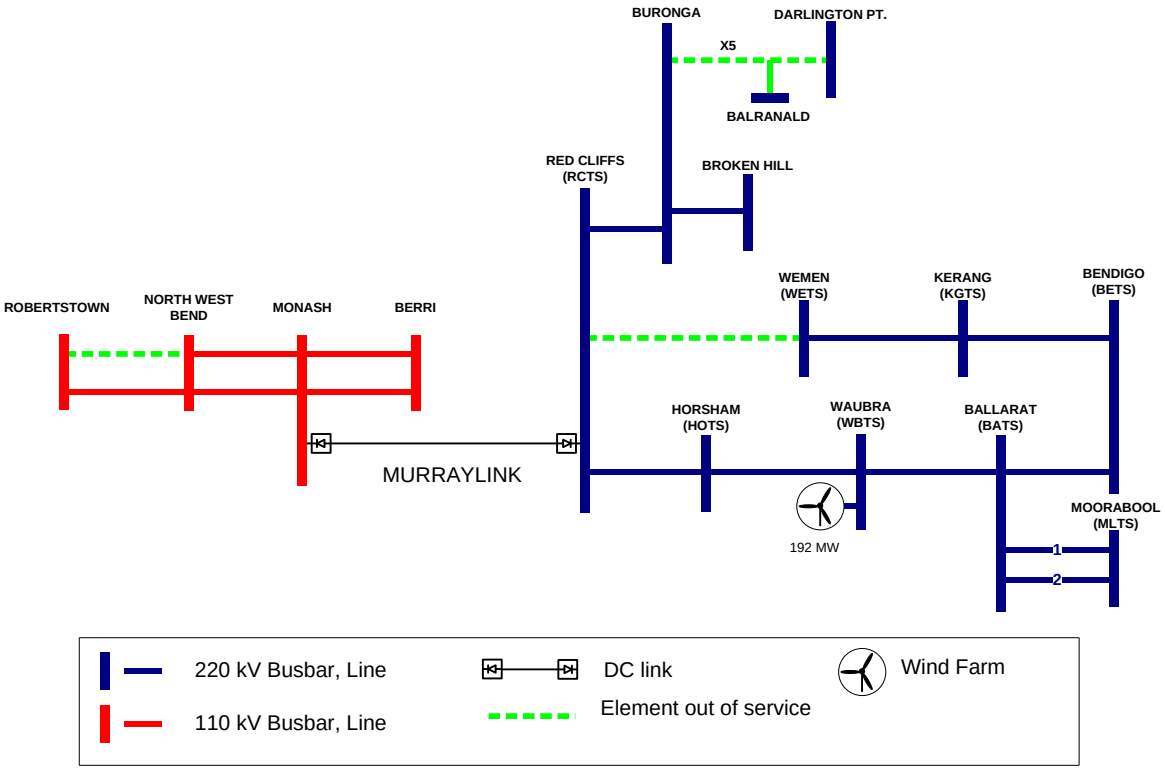
After analysing power system conditions, at 1300 hrs AEMO control room requested SP AusNet to off-load the Wemen–Redcliffs 220 kV Transmission Line at Redcliffs Terminal Station, to radialise the loads at Broken Hill, Redcliffs and Horsham Terminal Stations. In addition, the 66kV sub transmission system was separated between Ballarat and Horsham stations.

These reconfigurations reduced the requirement for flow on the Murraylink Interconnector from South Australia to Victoria and cleared the RTCA violations. System returned to secure operating state at 13:00.

The power system was not in a secure operating state from 1228hrs to 1300hrs.

The status of the power system after reconfiguration is shown in Figure 3.

Figure 3 - Status of the power system after load radialise operation, 1300 hrs 13 December 2012.



3.1 Supervisory Control and Data Acquisition System (SCADA) ranging

After radialising the network at 1300hrs, loading on the Waubra – Horsham 220kV Transmission Line increased. Line flows indicated in AEMO's SCADA for the Waubra – Horsham 220kV Transmission Line flattened at a value of approximately 260 MVA, as the SCADA MW transducers were over range, and were later found to have a range below the continuous rating of the transmission line. This SCADA range problem was a serious issue, as the control room operators were unaware of the true flow on the Waubra – Horsham 220kV Transmission Line until RTNET base case violations started at around 1441hrs. Control room investigated the security violation and identified that the SCADA values were incorrect. SCADA values for flows on the line were replaced with state estimator[2] values in AEMO's Energy Management System (EMS) at 1453 hrs.

3.2 Constraints[3]

At 1330 hrs the V>SML_BUDP_1, 2, 3 constraint equations for outage of the X5 line were blocked by AEMO. These constraint equations were violating and did not match the technical envelope of the power system after radialising the network, so they were blocked to prevent them incorrectly affecting the central dispatch process.

During this period, system normal constraints[4] were relied on to maintain power system security due that no outage constraints were available for the combined outage of the X5 and

[2] Power system state estimation is the act of estimating the state of the network from the redundant telemetry measurements. A state estimator is a tool that performs this process.
[3] Information relating to constraints is available from http://aemo.com.au/Electricity/Policies-and-Procedures/Congestion. Information relating to the Congestion Information Resource is available from http://aemo.com.au/Electricity/Market-Operations/Congestion-Information-Resource.

Robertstown - North West Bend No. 1 132 kV Transmission Lines, and AEMO's RTCA system was indicating secure operation of the power system.

Flow from South Australia to Victoria on the Murraylink Interconnector was required during this period to prevent overload on the Horsham - Waubra 220kV Transmission Line. The resulting flow from South Australia to Victoria on the Murraylink Interconnector occurred due to the action of system normal constraints from 1300 hrs to 1430 hrs.

3.3 Changing power flows

Changing market conditions along with change in Waubra Wind Farm generation changed power flows in Victoria from 1430 hrs.

From 1430 hrs to 1500 hrs dispatched generation in the Victoria region increased from 7,270 MW to 8,826 MW. After rebids were submitted to the central dispatch system for Murray Power Station, a 5 minute price spike of $12,899.90 /MWh occurred for DI 14:35, further rebids received for Murray Power Station and Valley Power Gas Station caused a 1,065 MW increase in Victoria generation in 5 minutes, from 7,359 MW at 1435 hrs to 8,424 MW at 1440 hrs. The increase in Victoria generation changed power flows on the power system.

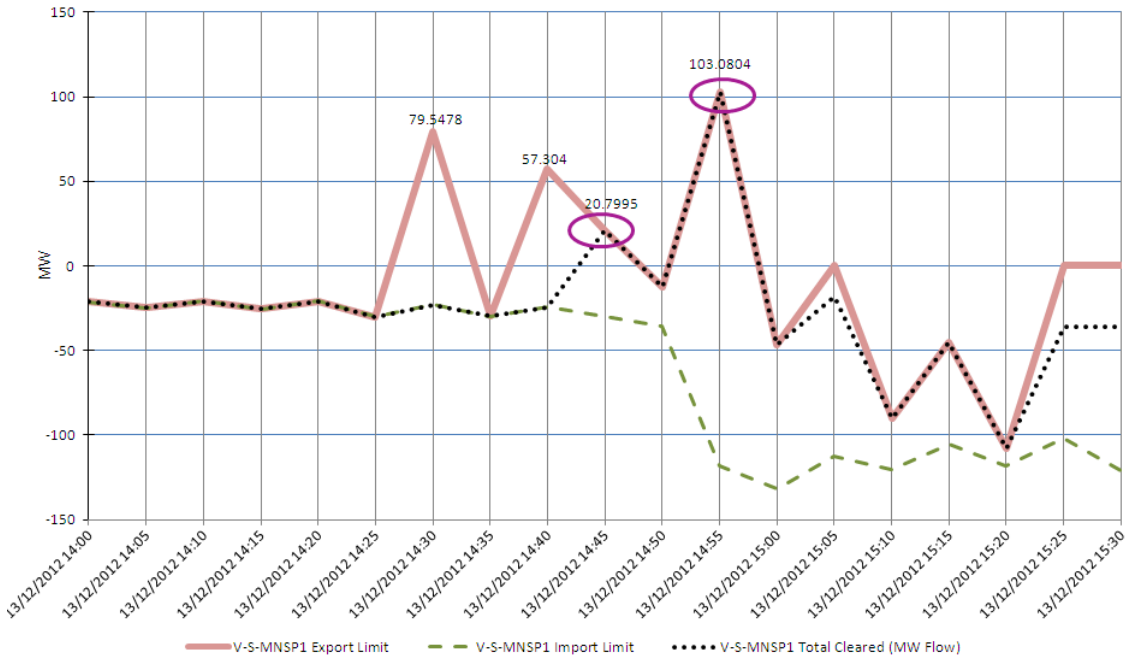
Waubra Wind Farm is non-scheduled generation and change in its generation had a direct impact on relaxing system normal constraints from 1438 hrs to 1458 hrs. Waubra Wind Farm generation increased rapidly from 2 MW at 1438 hrs to 100 MW at 1449 hrs and remained at around 100 MW until 1458 hrs.

Increase in Waubra Wind Farm generation decreased the flow to Waubra Terminal Station from Ballarat Terminal Station; this consequently decreased the flow to Ballarat Terminal Station from Moorabool Terminal Station. Decrease in the Moorabool to Ballarat line flow relaxed the constraint equation that was setting the limit on flow from South Australia to Victoria on the Murraylink Interconnector to avoid overloading on the Ballarat - Moorabool No.1 220 kV Transmission Line for loss of the Ballarat - Moorabool No.2 220 kV Transmission Line. This constraint was the main system normal constraint that was setting the flow from South Australia to Victoria on the Murraylink Interconnector after the load was radialised.

Increase in Victorian generation, including Waubra Wind Farm generation changed power flows on the power system, and system normal constraints that were previously setting negative export limits on the Murraylink Interconnector started to allow flow from Victoria to South Australia on the Murraylink Interconnector. Positive export limits were set on the Murraylink Interconnector for 14:30, 14:40, 14:45 and 14:55 DIs. For the 14:45 and 14:55 DIs the Murraylink Interconnector received a target from the central dispatch system for actual flow from Victoria to South Australia. Figure 4 below shows flow on the Murraylink Interconnector and its limits from 1400 hrs to 1530 hrs.

[4] System normal refers to the configuration of the power system where: (a) All transmission elements are in service; or (b) The network is operating in its normal network configuration. System normal constraints are the constraints applicable to this power system configuration.

Figure 4 - Murraylink Interconnector flow and its limits from 14:00 hrs to 15:30 hrs.



3.4 Overload of the Waubra-Horsham 220 kV Transmission Line

This flow on the Murraylink Interconnector from 1441 hrs to 1446 hrs and from 1451hrs to 1458hrs from Victoria to South Australia resulted in overloading of the Waubra - Horsham 220 kV Transmission Line. The Waubra - Horsham 220 kV Transmission Line was overloaded twice, once for 5 minutes from 1441 hrs to 1446 hrs with a maximum overload of 25 MVA at 1443 hrs and a second time for 6 minutes from 1451 hrs to 1457 hrs with a maximum overload of 117MVA at 1452 hrs.

In response to the actual overload of the Waubra – Horsham 220kV Transmission Line, at 1455 hrs the constraint set I-VSML_000 was invoked by AEMO to limit flow from Victoria to South Australia on the Murraylink Interconnector to 0 MW.

3.5 Low voltage at Horsham and Redcliffs

During this period of Waubra – Horsham 220kV Transmission Line overloads, the busbar voltages at Redcliffs and Horsham Terminal Stations reduced below the limit of 210 kV required to maintain a satisfactory operating state. Redcliffs Terminal Station had a busbar minimum voltage of 195 kV at 1452 hrs and Horsham Terminal Station had a busbar minimum voltage of 209 kV at 1452 hrs.

The constraint equation V^SML_NIL_3 is a system normal constraint designed to avoid voltage collapse[5] for loss of the Bendigo - Kerang 220kV Transmission Line. At 1450 hrs (for DI of 1455 hrs) the constraint bound and limited flow from Victoria to South Australia on the Murraylink Interconnector to 103 MW. If this constraint had not limited this flow, studies indicate there may have been voltage collapse at Horsham.

[5] Voltage collapse is a power system phenomenon in which the electro-magnetic field is not sustained and may result in shutdown of areas of the power system.

3.6 Restoration of the power system

At 1445 hrs the Robertstown - North West Bend No. 1 132 kV Transmission Line was returned to service, and from 1545 hrs to 1635 hrs the power system was progressively returned to its pre-incident configuration.

Summary of events during the incident are listed in table 1.

Table 1: Summary of events during the incident on 13 December 2012

Time	Events/Comments
12:27 hrs	Robertstown-North West Bend No.1 132 kV transmission line tripped. Real Time Contingency Analysis (RTCA) indicated violations for overload on Waubra-Horsham 220 kV line on trip of Bendigo-Kerang 220 kV line.
13:00 hrs	Wemen-Red Cliffs 220 kV transmission line opened at Red Cliffs to radialise loads. The 66 kV sub transmission system was separated between Ballarat and Horsham stations. These operations removed RTCA violations and the system returned to secure operating state.
13:00 hrs	MVA and MW SCADA values for Waubra-Horsham 220kV line were flat at around 260 MVA (250 MW) due to transducers over range. Control room operators were unaware of the true flow on the line until RTNET base case violations started at around 1441 hrs. System security violations investigated and SCADA values were replaced with state estimator values at 1453 hrs.
13:25 hrs	Constraints V>SML_BUDP_1,2,3,4 blocked and system normal constraints relied on to set a negative export limit on Murraylink that was required to maintain Murraylink target into Victoria. Assumption was based on high demand in Victoria.
14:30 hrs to 15:00 hrs	Victoria dispatched generation increased from 7,270 MW to 8,826 MW.
14:30 hrs, 14:40 hrs, 14:45 hrs, 14:55 hrs	Murraylink export limit became positive – potentially allowing flow from VIC to SA.
14:45 hrs and 14:55 hrs	Murraylink received positive targets and overload occurred on the Waubra - Horsham 220 kV transmission line.
14:45	North West Bend – Robertstown No. 1 132 kV transmission line returned to service.
14:53	MVA values on Waubra - Horsham 220 kV transmission line were replaced by state estimator values.
14:55	Constraint set I-VSML_000 invoked. This sets upper transfer limit to 0 MW on Murraylink from Victoria to South Australia.
15:45 hrs, 15:52 hrs and 16:35 hrs respectively	Actions taken to return system to normal configuration: Constraints Unblocked V>SML_BUDP_1, V>SML_BUDP_2, V>SML_BUDP_3.

	Victoria State Grid restored to normal configuration. Wemen-Red Cliffs 220 kV transmission line closed. Ballarat to Horsham 66kV sub transmission system closed. Constraint set I-VSML_000 revoked.

4. Immediate Actions Taken

From 1300 hrs to 1552 hrs the Redcliffs - Wemen 220 kV Transmission Line was opened to radialise the Victoria transmission system around Redcliffs and the 66 kV sub transmission system was separated between Ballarat and Horsham stations. These arrangements were used to re-secure the power system following loss of the North West Bend - Robertstown No. 1 132 kV transmission line.

From 1455 hrs to 1635 hrs, AEMO invoked the constraint set I-VSML_000 to limit flow on from Victoria to South Australia on the Murraylink Interconnector to 0 MW.

5. Follow-up Actions

On 22 January 2013, SP AusNet informed AEMO that they had performed an initial assessment of other transducer ranges on the system and had not found any similar issues however further detailed analysis will be carried out.

On 11 February 2013, SP AusNet advised AEMO that they have changed MW transducer ranges at Waubra and Horsham Stations to have a range of -450 MW to +450 MW. This is believed to be adequate to cover the rating of this transmission line.

AEMO has now classified the X5 line outage as a high impact outage, and updated the high impact outage assessment procedure accordingly. This procedure now specifies actions that need to be taken to ensure secure operation of the power system during this outage.

On 25 March 2013, SP AusNet expressed a view that they applied instrumentation ranges in accordance with VENCorp's Protection and Control Requirement (PCR) issued in December 2008 and by the events of 13 December 2013 the original PCR settings for the Waubra - Horsham 220 kV transmission line were inadequate.

From AEMO's recent review of the PCR it appears that the instrumentation range was set by VENCorp as 250 MW WBTS – HOTS (from bus) and 450 MW HOTS – BATS (to bus). Instead, the range should have been set to 450 MW WBTS – HOTS (from bus) and 250 MW HOTS – BATS (to bus). This appears to be a copy and paste error that has not previously been picked up.

6. Power System Security Assessment

The power system was not in a secure operating state from 1228 hrs after the Robertstown – North West Bend No. 1 132 kV Transmission Line contingency until 1300 hrs when each of the load groups (Wemen, Kerang) and (Broken Hill, Red Cliffs and Horsham) were radialised. This was a total period of 32 minutes.

The power system was not in a satisfactory operating state for two periods totalling 11 minutes when the loading on the Waubra-Horsham 220 kV Transmission Line exceeded the thermal rating on two occasions.

1. 1441 hrs to 1446 hrs = 5 minutes Max overload 25 MVA at 1443 hrs.
2. 1451 hrs to 1457 hrs = 6 minutes Max overload 117 MVA at 1453 hrs.

During these periods the measured SCADA values for line flows were not correct, so AEMO used state estimator values where the flows are calculated from a summation of the output of Waubra Wind Farm and the power flowing on Waubra - Ballarat 220 kV transmission line.

7. Conclusions

On 13 December 2012, the power system was not in a secure operating state from 1228 hrs to 1300 hrs, for a total period of 32 minutes; and the loading on the Waubra – Horsham 220kV Transmission Line exceeded the continuous thermal rating of the line and consequently the power system was in an unsatisfactory condition on two occasions for a total duration of 11 minutes between 1441 hrs to 1457 hrs.

Insecure operating state was a result of an unplanned high impact outage that was followed by another unplanned outage. Unsatisfactory operating state was a result of incorrect ranging of SCADA transducers resulting in a lack of awareness by AEMO's operators of the true state of the power system, a lack of constraints that matched the power system technical envelope, and rapidly changing market conditions.

AEMO re-secured the power system by reconfiguration of the power system. AEMO returned the power system to satisfactory operation by replacing the incorrect SCADA measurements with state-estimator values, and by invocation of a discretionary constraint[6] on the Murraylink Interconnector.

AEMO will perform a review of the instrumentation ranges for the Victoria Transmission Network by 15 May 2013, and any additional work required as a result of this review will be completed by 31 December 2013.

8. Recommendations

1. AEMO should review the process for issuing Protection and Control Requirements to ensure controls are in place to minimise the likelihood of the re-occurrence of the copy and paste error by 31 December 2013.
2. AEMO should perform a review to check that instrumentation ranges in the Victorian transmission network are adequate to measure the flows consistent with the Winter Ratings of the transmission lines by 15 May 2013.
3. AEMO should correct any issues identified during the review by 31 December 2013.

[6] Discretionary constraint is a constraint that is used to limit an interconnector or generation to less than or equal to, equal to, or greater than or equal to a fixed value.