Power System Operating Incident Report – Trip of Tarrone – Moorabool No.1 500 kV Line on 8 September 2013

PREPARED BY: AEMO Systems Capability

DATE: 14 November 2013

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Version Release History

VERSION	DATE	BY	CHANGES	CHECKED BY	AUTHORISED BY
1	15 Nov 2014	P McEniery	FINAL	S Darnell	P Biddle
2	15 July 2014	S Darnell	Amended Section 9	S Darnell	P Biddle

Incident Classifications

Time and date and of incident	1850 hrs 8 September 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	Significant – Loss of load or generation exceeding 50 MW but less than 250 MW
Associated reports	Power System Operating 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.

Abbreviations and Symbols

Abbreviation	Term
AEMO	Australian Energy Market Operator
APD	Alcoa Portland
ARPS	Anti-Resonance Protection Scheme
CB	Circuit Breaker
CBF	Circuit Breaker Fail
DI	Dispatch Interval
HYTS	Heywood Terminal Station
kV	Kilovolt
MLTS	Moorabool Terminal Station
MW	Megawatt
NER	National Electricity Rules
TRTS	Tarrone Terminal Station

Contents

1 Introduction

This report reviews a power system operating incident that occurred on 8 September 2013 in the Victorian region at Heywood Terminal Station. AEMO is required to review this incident as it 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. 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 security[2].

This report is based upon information provided by AEMO[3] and SP AusNet[4]. All references to time in this report are to National Electricity Market time (Australian Eastern Standard Time).

2 The Incident

The Tarrone Terminal Station (TRTS) – Moorabool Terminal Station (MLTS) No.1 500 kV transmission line tripped out of service at 1850 hrs 8 September 2013. The Alcoa Portland (APD) – Heywood Terminal Station (HYTS) – TRTS No.1 500 kV line was out of service at the time of the trip. As a result Macarthur Wind Farm was islanded and reduced generation from 55 MW to 0 MW.

The TRTS-MLTS No.1 500 kV line tripped due to the operation of the circuit breaker fail (CBF) function of the Anti-Resonance Protection Scheme[5] (ARPS) on the out of service APD-HYTS-TRTS No.1 500 kV line. The CBF operation of the ARPS was not expected.

3 Participant Investigations

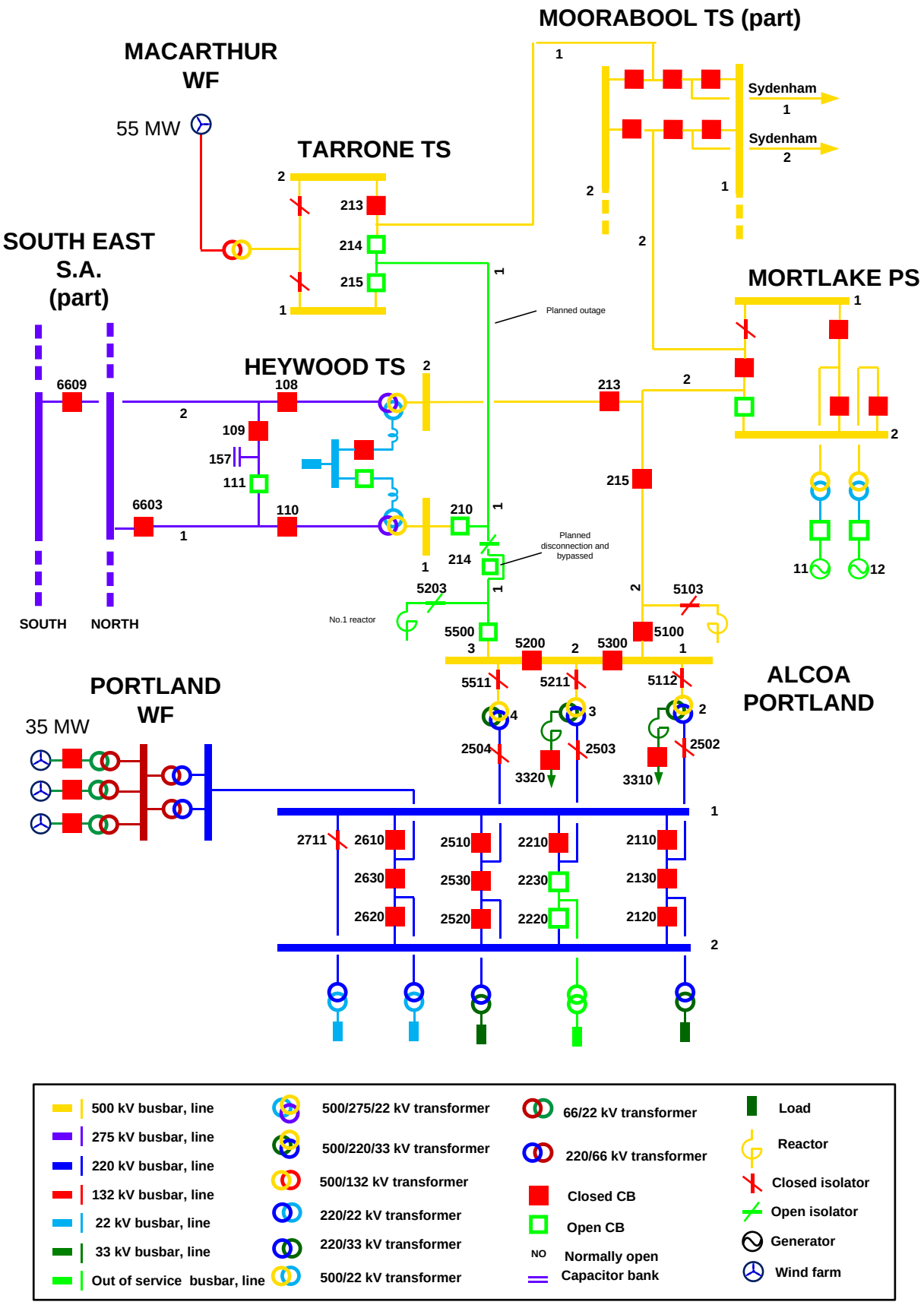
AEMO and SP AusNet investigated the incident. The investigation found there was a resonant condition on the out of service APD-HYTS-TRTS No.1 500 kV transmission line. The resonant voltages were higher than was predicted in power system simulations carried out by AEMO after a previous incident on 4 July 2013[6]. During planned switching to return the APD-HYTS-TRTS No.1 500 kV line to service, the CBF function of the ARPS operated due to the resonant voltages.

4 Pre-Incident State

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 the APD-HYTS-TRTS No.1 500 kV transmission line out of service and the 500 kV CB 214 at HYTS bypassed for planned work.

[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] See for Appendix 1 for a brief overview of the ARPS.
[6] See incident report on the AEMO website for further detail.

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



5 Summary of events

The sequence of events comprising the incident are itemised in Table 1. The incident spanned approximately 43 minutes from 1833 hrs before the power system was returned to the pre-incident state.

At 0648 hrs the APD-HYTS-TRTS No.1 500 kV transmission line had been taken out of service to bypass the 500 kV CB 214 at HYTS for planned work.

The CBF function of the ARPS remained in service on detection of high voltage only. After a similar incident on 4 July 2013, the ARPS CBF voltage detection settings had been adjusted from 30 kV to 260 kV. This adjustment was to avoid spurious operation of the ARPS.

At 1833 hrs the isolator adjacent to the 500 kV CB 214 at HYTS was closed in preparation to return the APD-HYTS-TRTS No.1 500 kV transmission line to service. The connection of the two line sections gave rise to resonant voltages on the line. These voltages were not expected to exceed the threshold of the CBF function of the ARPS and cause the ARPS to operate. At this stage the actual resonant voltage on the white phase was slightly below the ARPS trip setting of 260kV.

The resonant condition caused current to flow through the neutral reactor of the 500 kV No.1 line reactor at APD, marginally in excess of the reactor's continuous current rating of eight amperes. The reactor overcurrent protection operated, targeting the trip of the APD-HYTS-TRTS No.1 500 kV transmission line. No circuit breakers opened as the APD-HYTS-TRTS No.1 500 kV transmission line was already out of service.

At 1850 hrs, SP AusNet attempted to re-energise the APD-HYTS-TRTS No.1 500 kV transmission line via the 500 kV CB 215 at TRTS. Immediately the reactor overcurrent protection tripped the 500 kV CB 215 at TRTS out of service.

In addition, the CBF fail function of the ARPS operated as there was a transient increase in the white phase to ground voltage, in excess of 260 kV. This exceeded the voltage detection threshold of 260 kV of the CBF function of the ARPS. The ARPS sent a signal to trip the TRTS-MLTS No.1 500 kV transmission line and then close the 500 kV CB 214 at TRTS.

The faster operating overcurrent trip signal blocked the ARPS close signal and as such the 500 kV CB 214 at TRTS remained out of service. Therefore the resonant condition persisted after the protection operated, and the neutral reactor of the 500 kV No.1 line reactor at APD continued to be overloaded.

The final outcome was the trip of the TRTS-MLTS No.1 500 kV line and the islanding of Macarthur Wind Farm. Macarthur Wind Farm reduced in output from 55 MW to 0 MW as a result.

Table 1 – Summary of events during the incident

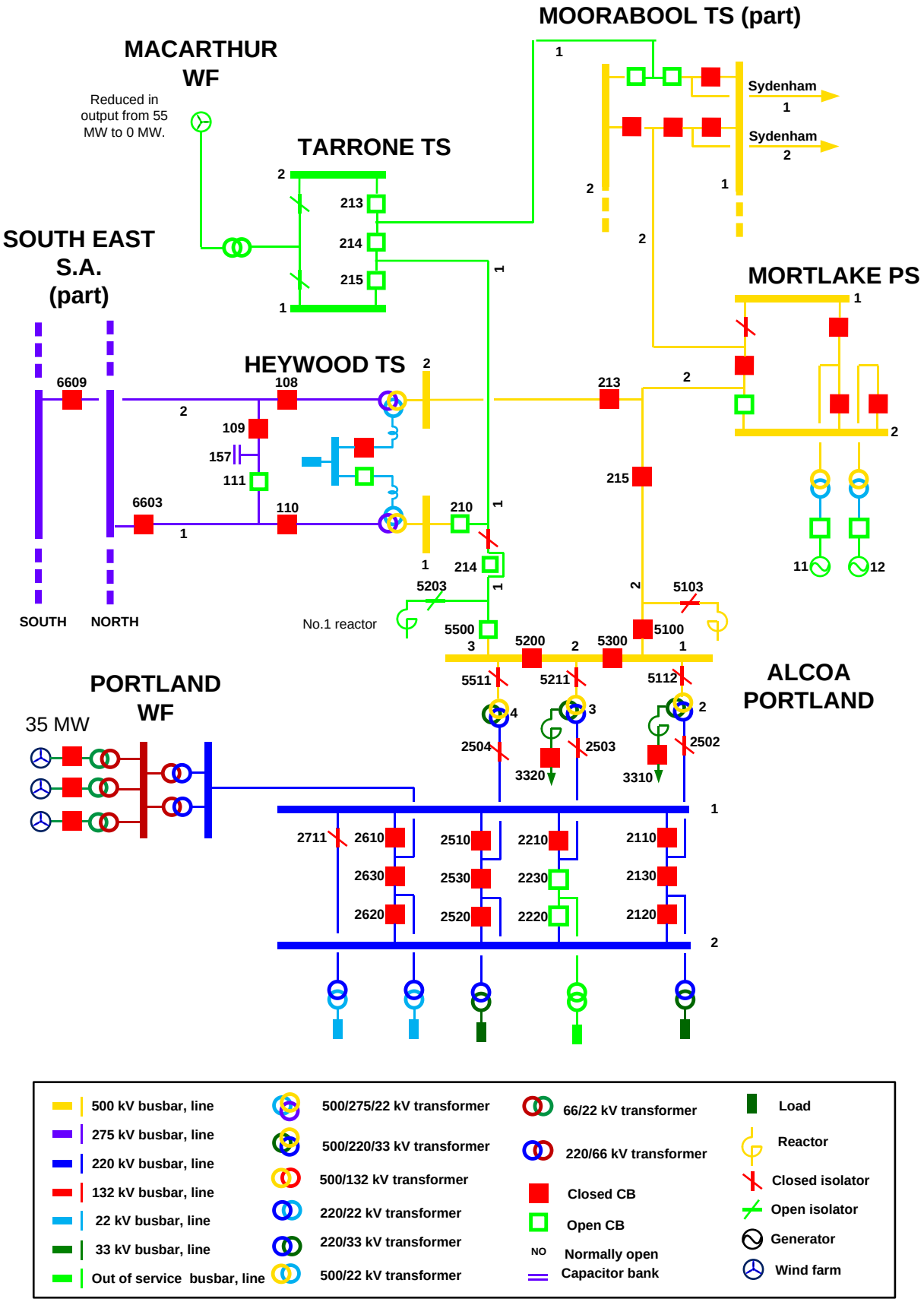
Date and Time	Event
0648 hrs 8 September 2013	APD-HYTS-TRTS No.1 500 kV transmission line taken out of service, in order to bypass the 500 kV CB 214 at HYTS for planned work.
1833 hrs 8 September 2013	Isolator adjacent to the 500 kV CB 214 at HYTS closed. A resonant condition is created on the APD-HYTS-TRTS No.1 500 kV line.
1850 hrs 8 September 2013	The 500 kV CB 215 at TRTS closed by SP AusNet.
1850 hrs 8 September 2013	Overcurrent protection on No.1 500 kV line reactor at APD trips the 500 kV CB 215 at TRTS.
1850 hrs 8 September 2013	CBF function of the ARPS operates.
1850 hrs 8 September 2013	TRTS-MLTS No.1 500 kV transmission line trips out of service.
1850 hrs 8 September 2013	Macarthur Wind Farm islanded and reduces in generation from 55 MW to 0 MW.
1854 hrs 8 September 2013	TRTS-MLTS No.1 500 kV transmission line is returned to service.
1916 hrs 8 September 2013	Isolator adjacent to the 500 kV CB 214 at HYTS opened.

Date and Time	Event
2105 hrs 8 September 2013	Following planned switching, APD-HYTS-TRTS No.1 500 kV transmission is returned to service.
2125 hrs 8 September 2013	Macarthur Wind Farm returned to service.

6 Post Incident State

The status of the power system immediately after the trips is shown in Figure 2. The diagram shows the TRTS-MLTS No.1 500 kV transmission line out of service and Macarthur Wind Farm islanded.

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



7 Immediate Actions

At 1854 hrs the TRTS-MLTS No.1 500 kV transmission line was returned to service, four minutes after the initial event.

AEMO must take action to return the power system to a secure operating state within thirty minutes following a contingency event[7]. The TRTS-MLTS No.1 500 kV transmission line was returned to service before the commencement of the next Dispatch Interval (DI) at 1855 hrs. As such AEMO did not invoke any constraint sets for the outage of the TRTS-MLTS No.1 500 kV transmission line.

AEMO and SP AusNet reviewed protection alarms, circuit breaker alarms, voltage measurements and current measurements to assess what had occurred. AEMO's immediate assessment was that the incident was due to protection operating correctly.

AEMO and SP AusNet determined that prior to closing the 500 kV CB 215 at TRTS there were high resonant voltages on the APD-HYTS-TRTS No.1 500 kV line. This resonant condition had to be cleared before closing the 500 kV CB 215 at TRTS in order to prevent a re-occurrence of the incident.

At 1916 hrs the isolator at the 500 kV CB 214 at HYTS was opened. This removed the resonant condition on the APD-HYTS-TRTS No.1 500 kV transmission line. The overload of the No.1 500 kV line reactor's neutral reactor at APD was also removed.

AEMO and SP AusNet agreed upon a switching plan to return the APD-HYTS-TRTS No.1 500 kV transmission line to service by:

a. Taking the TRTS-MLTS No.1 500 kV line out of service and then closing the 500 kV CB 214 at TRTS. This would prevent a resonant condition on the APD-HYTS-TRTS No.1 500 kV transmission line when the isolator at the 500 kV CB 214 at HYTS was closed. This switching would also island Macarthur Wind Farm from the power system; and then

b. Close the isolator at the 500 kV CB 214 HYTS, creating an isolated segment between APD, HYTS, TRTS and MLTS free of any resonance; and then

c. Re-energise the APD-HYTS-TRTS No.1 500 kV line and TRTS-MLTS No.1 500 kV line in sequence from MLTS, HYTS and APD.

AEMO invoked constraints sets V-MLTR[8], F-V-MLTR[9] and V-MACARTHUR_ZERO[10] in DI ending 2045 hrs, in preparation for the planned outage of TRTS-MLTS No.1 500 kV transmission line.

By 2105 hrs SP AusNet completed the switching and returned the APD-HYTS-TRTS No.1 500 kV transmission line and TRTS-MLTS No.1 500 kV transmission line to service. The 500 kV CB 214 CB at HYTS remained bypassed and disconnected from the power system. AEMO revoked all constraints invoked after the planned outage of the TRTS-MLTS No.1 500 kV transmission line in DI ending 2105 hrs.

At 2125 hrs Macarthur Wind Farm returned to service.

8 Follow-up Actions

The incident was analysed in the following 24 hours by AEMO and SP AusNet. AEMO advised its operating staff that because of the unexpectedly high resonant voltages, a detailed investigation was needed. Pending this investigation the loss of the APD-HYTS-TRTS No.1 and MLTS-TRTS No.1 500 kV lines was to be regarded as a credible contingency, for the duration of the bypass of the 500 kV CB 214 at HYTS.

[7] NER v57 Clause 4.2.6 (b)
[8] Out = Tarrone to Moorabool (TRTS-MLTS) No.1 500 kV line.
[9] Out = Tarrone to Moorabool (TRTS-MLTS) No.1 500 kV line – FCAS requirements.
[10] Macarthur Wind Farm upper limit of 0 MW.

At 1427 hrs 9 September 2013 AEMO issued Market Notice 43257. This was to advise that the loss of the MLTS-TRTS No.1 and APD-HYTS-TRTS No.1 500 kV transmission lines was reclassified as a credible event.

With the bypass of the 500 kV CB 214 at HYTS, the auxiliary contact detection CBF function of the ARPS remained out of service. The auxiliary contact detection function operates faster than the reactor overcurrent protection. Until the auxiliary contact detection function was restored, the voltage detection function was unsuitable to clear a resonant condition during a similar incident.

AEMO instructed SP AusNet to adjust the voltage threshold from 260 kV to 100 kV. This ensured that for a fault the ARPS would operate before the overcurrent protection. Therefore the 500 kV CB 214 at TRTS would close and prevent a resonant condition from forming.

When the 500 kV CB 214 at HYTS was returned to service on 15 September 2013, the auxiliary contact detection CBF function of the ARPS was restored. Therefore, the ARPS would operate first and ensure that the 500 kV CB 214 at TRTS is closed, breaking any resonant condition. The voltage threshold of the CBF function of the ARPS was restored from 100 kV to 260 kV. This voltage threshold would prevent a re-occurrence of the incident that occurred on 4 July 2013.

At 1555 hrs 15 September 2013, AEMO issued Market Notice 43316, advising the market that the reclassification advised under Market Notice 43257 was cancelled.

AEMO had reviewed the protection settings of the ARPS following the previous incident that occurred on 4 July 2013. Following this review AEMO instructed SP AusNet to implement the voltage threshold setting of 260 kV. This was based upon power system simulations that showed the highest possible phase to ground voltage on the fully (3 pole) isolated line with the 500 kV CB 214 at HYTS failing to open was 110 kV. The voltage threshold setting was intended to be high enough to avoid spurious operation of the ARPS.

During the incident on 8 September 2013, the highest white phase to ground voltage on the isolated APD-HYTS-TRTS No.1 500 kV line was observed to be slightly below 260 kV. AEMO will again review its power system simulation, and issue new CBF voltage threshold settings to SP AusNet if required.

9 Power System Security

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

The 500 kV No.1 line neutral reactor at APD was loaded between 75% and 100% of its continuous rating from 1833 hrs to 1916 hrs on 8 September 2013. This is not considered to be a power system security violation as the line reactor was loaded within its continuous rating. However, for the system configuration at the time of the incident, including bypass of the 500 kV CB 214 at HYTS, the ARPS and neutral reactor overcurrent protection were not correctly co-ordinated. With the 500 kV CB 214 at HYTS in service, the ARPS and reactor overcurrent protection are correctly co-ordinated to prevent over loading of the neutral reactor. For future outages of the 500 kV CB 214 at HYTS, the ARPS scheme will be adjusted, for the duration of the outage, to ensure correct co-ordination with the neutral reactor overcurrent protection.

10 Conclusions

This incident that occurred in Victoria at 1850 hrs 8 September 2013 was initiated by a resonant condition causing unexpectedly high voltages on the APD-HYTS-TRTS No.1 500 kV transmission line. The incident was aggravated by protection not being suitable to clear the resonant condition.

AEMO is satisfied that appropriate measures are being taken to mitigate the risk of a similar incident re-occurring in the future. That is, with the return to service of the 500 kV CB 214 at HYTS the auxiliary contact detection CBF function of the ARPS will be suitable to prevent a similar incident. Furthermore AEMO will review its power system simulations, and issue new CBF voltage threshold settings to SP AusNet if required.

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

11 Recommendations

1. AEMO to review its power system simulations used in developing protection settings for the ARPS, and if necessary issue revised CBF voltage threshold settings for the ARPS. To be completed by 31 December 2013.

Appendix 1 Overview of Anti-Resonance Protection Scheme (ARPS)

The ARPS is designed to prevent high voltages being induced on 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 the 500 kV CB 214 at HYTS 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.

Detection of circuit breaker failure is achieved either by:

- Polling the status of the circuit breaker auxiliary contacts, or
- Voltage present on the line after the line is disconnected indicating a resonant condition.