Power System Operating Incident Report – Trip of APD-Heywood-Tarrone No.1 500 kV Line, Moorabool-Tarrone No.1 500 kV Line and APD No.3 500 kV Busbar on 9 May 2014

PREPARED BY: Systems Capability

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Version Release History

VERSION	DATE	BY	CHANGES	CHECKED BY	AUTHORISED BY
1	29 Aug 2014	R Burge	FINAL	S Darnell	P Biddle

Incident Classifications

Time and date and of incident	0647 hrs Friday 9 May 2014
Region of incident	Victoria
Affected regions	Victoria
Event type	TG – Loss of Transmission Element(s) and Generating Units
Primary cause	OE & CON – Operating Error and Non-conformance
Impact	S (Significant)
Associated reports	1. Power System Operating Incident Report: Trip of Tarrone – Moorabool No.1 500 kV Line on 8 September 2013 2. 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

Abbreviation	Term
AEMO	Australian Energy Market Operator
A-H-T No.1 Line	APDTS-Heywood-Tarrone No.1 500 kV Transmission Line
APD	Alcoa Portland
APDTS	Alcoa Portland Terminal Station
APDTS No.3 Bus	No.3 500 kV Busbar at Alcoa Portland
ARPS	Anti-Resonance Protection Scheme
AusNet	AusNet Services (formerly known as SP AusNet)
CB	Circuit Breaker
CBF	Circuit Breaker Fail
CB 210	500 kV Circuit Breaker 210 at Heywood
CB 214	500 kV Circuit Breaker 214 at Heywood
CB 5500	500 kV Circuit Breaker 5500 at APDTS
Heywood	Heywood Terminal Station
kV	Kilovolt
M1 Transformer	Heywood M1 500/275 kV Transformer
Moorabool	Moorabool Terminal Station
M-T No.1 Line	Moorabool–Tarrone No.1 500 kV transmission line
MW	Megawatt
NER	National Electricity Rules
ROI	Remotely Operated Isolator
Tarrone	Tarrone Terminal Station

1 Introduction

This report reviews a power system operating incident[1] that occurred on Friday 9 May 2014 in Victoria.

The purpose of this incident review is to assess power system security over the course of the incident. The National Electricity Rules (NER) require 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 AusNet Services (AusNet)[3], Alcoa Portland (APD)[4] and AEMO. National Electricity Market time (Australian Eastern Standard Time) is used in this report.

2 The Incident

On Friday 9 May 2014 at 0647 hrs the APD Terminal Station (APDTS) – Heywood Terminal Station (Heywood) – Tarrone Terminal Station (Tarrone) No.1 500 kV transmission line (A-H-T No.1 Line) tripped due to a single phase earth fault. This trip resulted from a switching error at Heywood. The trip was then immediately followed by:

1. The trip of APDTS No.3 500 kV Busbar and No. 4 Transformer.
2. The trip of Moorabool Terminal Station (Moorabool) – Tarrone No.1 500 kV transmission line (M-T No.1 Line).
3. The islanding of Macarthur Wind Farm resulting in a loss 229 MW of generation.
4. The trip of Portland Wind Farm resulting in the loss of 47 MW. This trip was later identified as a coincidence. The wind farm had been taken out of service for maintenance.

The reason for investigating this incident is that the events subsequent to the A-H-T No.1 Line trip were not expected for a single phase earth fault on the A-H-T No.1 Line.

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

3 Participant Investigations

This incident spanned the networks of AusNet and APD. The network owner investigations revealed a series of three sequential events explained below.

3.1 AusNet – trip of the A-H-T No.1 Line

AusNet investigated the trip of the A-H-T No.1 Line and found that it was caused by a switching error associated with a planned outage of the Heywood M1 500/275 kV Transformer (M1 Transformer).

A Remotely Operated Isolator (ROI) at Heywood malfunctioned during switching for the outage of M1 Transformer (see diagram in Appendix 1). When the ROI was opened, the white phase ROI gearbox seized causing the conductor blade to remain in the closed position. On site operators then failed to correctly

[1] 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 (NER) - NER 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 the Transmission Network Service Provider in the Victoria region. 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] Alcoa Portland is the entity that operates the Portland Aluminium Plant at Portland in Victoria

observe switching procedures and closed an earth switch on the transformer side of the ROI, thereby connecting the live white phase to earth.

Both X and Y line protection systems on the A-H-T No.1 Line operated correctly to clear the fault via the following events:

1. At Tarrone, the white phase of the CBs connected to the A-H-T No. 1 Line opened.
2. At Heywood, the white phase of CB 214 on the A-H-T No. 1 Line opened – this action splits the de-energised line to prevent an induced resonant voltage. See Appendix 3 for an explanation of the Anti-Resonance Protection Scheme (ARPS) which controls this feature.
3. At Heywood, a trip signal was sent to APDTS[5]
4. At APDTS, the white phase of CB5500 on the A-H-T No.1 Line opened (in response to Point 3)

The following events were then expected:

- A two second delay, then a single phase auto-reclose attempt on the A-H-T No. 1 Line, followed by
- A three phase trip and lockout of the A-H-T No.1 Line because the earth switch had imposed a permanent fault.

However, these expected events did not occur because they were eclipsed by further events at APDTS (during the two second delay above).

3.2 Portland Aluminium – trip of No.3 500 kV Busbar and No.4 Transformer at APDTS

APD investigated the unexpected trip of the APDTS No.3 Busbar and found that a Circuit Breaker Fail[6] (CBF) timer was incorrectly initiated for CB5500 at APDTS.

The trip signal from Heywood (Point 3 in Section 3.1) correctly initiated the white phase CBF (single phase) timer and incorrectly initiated the three phase CBF timer for CB5500. The white phase CBF timer did not time out because the white phase of CB5500 correctly opened. The three phase CBF timed-out because the Red and Blue phases remained correctly closed. The three phase CBF timer then initiated the following operations (correct for the CBF input scenario):

1. At APD, CBs 5200, 2510 and 2530 opened on three phases. This opened the APDTS connection to the A-H-T No.1 line and de-energised the APDTS No.3 Busbar and No.4 500/220/33 kV transformer.
2. Send a trip signal to Tarrone to open the A-H-T No.1 Line CBs on three phases (white phase already open). This trip signal failed (see Section 3.3) and the A-H-T No. 1 Line CBs at Tarrone remained closed.
3. Send a trip signal to Heywood to open CB 214 on three phases. The trip signal was successful and CB214 opened. This action split the A-H-T No. 1 Line to prevent an induced resonant voltage.

APD found that the three phase CBF timer was incorrectly initiated by a design error in a recently implemented Emergency Restoration of Supply (EROS) scheme at APDTS. APD permanently disconnected the EROS scheme from the CBF to rectify the design error.

[5] The A-H-T No. 1 Line is protected as a three terminal line that has two protection zones: the Heywood-Tarrone zone and the Heywood- APD zone. For a fault in one zone a trip signal is sent to the other zone. For this incident the fault was in the Haywood-Tarrone zone so a trip signal was sent to the Heywood-APD zone.

[6] Circuit Breaker Fail timers are initiated when a CB receives a trip signal. The objective is to confirm the breaker has opened and if not initiate further events to compensate for the failure. If the CB correctly opens then the timer is cancelled and no further events are initiated because the breaker successfully opened. If the CB fails to open the timer is not cancelled and times out and then initiates further protection operations to compensate for the failed CB.

3.3 AusNet – trip of Moorabool - Tarrone No.1 Line

AusNet investigated the unexpected trip of the M-T No.1 Line. AusNet found that the CBF trip signal from APDTS to Tarrone (Point 2 in Section 3.2) was not sent from APDTS. As a result of the failed trip signal the following events occurred:

- At Tarrone, the A-H-T No.1 Line CBs remained closed on Red and Blue phases. These CBs should have opened in response to the trip signal from APDTS.
- At Heywood the ARPS detected a high voltage on the red and blue phases of the A-H-T No. 1 Line (due to the CBs at Tarrone not opening) in the presence of a trip signal from ADPTS[7]. As a result the ARPS sent trip signals to Tarrone, Moorabool and Heywood (correct for the ARPS input scenario) which initiated the following events:
    1. At Moorabool, the M-T No.1 Line CBs opened. This action islanded Macarthur Wind Farm.
    2. At Tarrone the busbar CBs opened and the centre CB closed.
    3. At ADPTS, CB550 opened on red and blue phases (white already open)

AusNet and APD will arrange joint tests to determine why the CBF trip signal, from APDTS to Tarrone, was not sent from APDTS.

3.4 Cumulative Result

For a permanent single phase earth fault at Heywood the expected outcome is:

- A-H-T No.1 Line open at each terminal (APDTS, Heywood and Tarrone), and
- CB 214 at Heywood open to prevent an induced resonant voltage.

The cumulative result of the single phase earth fault at Heywood, the incorrect CBF operation at APDTS, and the failed trip signal from APDTS to Tarrone, was:

- A-H-T No. 1 line open at each terminal
- CB214 at Heywood open
- M-T No. 1 line open at each terminal
- No. 3 busbar at APDTS de-energised
- No. 4 transformer at APDTS de-energised
- Macarthur Wind Farm islanded

4 Immediate Response

This section assesses the immediate response to the incident. AEMO invoked constraint sets V-HYTR[8], F-V-HYTR[9], V-MLTR[10], F-V-MLTR[11] and V-MACARTHUR_ZERO[12] in the dispatch interval ending 0655 hrs (within 10 minutes). These constraints ensured that the power system was returned to and remained in a secure operating state[13].

[7] This initiated an ARPS CBF for CB214 due to the input scenario – See Appendix 3
[8] Out = Heywood to Tarrone (HYTS-TRTS) No.1 500 kV line
[9] Out = Heywood to Tarrone (HYTS-TRTS) No.1 500 kV line – FCAS Requirements
[10] Out = Moorabool to Tarrone (MLTS-TRTS) No.1 500 kV line
[11] Out = Moorabool to Tarrone (MLTS-TRTS) No.1 500 kV line – FCAS Requirements
[12] Macarthur Wind Farm upper limit of 0 MW
[13] 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).

No other immediate actions were required to maintain power system security.

5 Follow-up Response

This section assesses the follow-up response to resolve the incident.

AusNet manually opened the white phase of the failed ROI at Heywood. This ROI will remain in manual mode until the automated mechanism of the ROI is repaired at a later date.

The affected transmission elements were then returned to service at the following times:

- At 0740 hrs the A-H-T No.1 Line and M-T No.1 Line (53 minutes after the initial event).
- At 0745 hrs the APDTS No.3 500 kV Bus.
- At 0753 hrs Macarthur Wind Farm.

At 0800 hrs AEMO revoked all constraint sets that were invoked after the event. The power system was then configured as intended for the outage of M1 Transformer.

AEMO issued Market Notice 45697 at 0809 hrs, 82 minutes after the event, to notify the market of the non-credible contingency event[14].

AEMO issued Market Notice 45701 at 1139 hrs to notify the market that the incident had not be reclassified as a credible contingency event. AEMO considered that the trip of A-H-T and M-T No.1 Lines were consistent with an ARPS operation, and that the trip of APDTS No.3 500 kV busbar was consistent with a failed CB 5500 (CBF) at APDTS. Based on this information AEMO considered the event unlikely to reoccur[15].

Subsequently, AusNet identified that an induced voltage had not been present on A-H-T No. 1 Line and that the 3-phase CBF on CB 5500 had incorrectly operated. Based on this information AEMO reclassified this event as a credible contingency. At 1910 hrs on 9 May 2014 AEMO issued Market Notice 45702 to notify the market of the following credible contingency event:

The simultaneous trip of:

- APDTS – HYTS – TRTS No.1 Line
- MLTS – TRTS No.1 Line
- APDTS No.3 500 kV Busbar
- Portland Wind Farm

AEMO issued Market Notice 45710 at 1122 hrs on 12 May 2014 to notify the market that Portland Wind Farm had been removed from the reclassification. AEMO initially identified Portland Wind Farm as having tripped at 0647 hrs due to the fault on the A-H-T No.1 Line. Portland Wind Farm later notified AEMO that the wind farm had been shut down for maintenance, coincident with the incident, and did not trip due to the incident.

APD investigated the cause of the incorrect three phase CBF signal for CB 5500 and found that the erroneous CBF signal was caused by a DC feedback circuit. This circuit was inadvertently created during the implementation of an Emergency Restoration of Supply (EROS) scheme at APDTS. On 12 May 2014 APD removed the connection links from EROS scheme to the CBF timer to permanently resolve the incorrect signal.

[14] AEMO, *Power System Security Guidelines,* Section 10.3 - AEMO is required to notify the market of a non-credible contingency within two hours of the event.

[15] For a non credible contingency event 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.

The amended reclassification specified in Market Notice 45710 will remain in place until the reason for the failed 3-phase remote trip signal from APDTS to Tarrone is identified.

AusNet and APD will jointly determine to the reason that the protection trip signal was not sent from APDTS. As of Aug 2014 the date of the joint tests had not been scheduled.

6 Power System Security

This section assesses how power system security was managed over the course of the incident[16].

The power system remained secure over the course of this incident and no load was lost as a result of this incident. Power system frequency and voltage remained within limits and the fault was cleared within required timeframes[17]. AEMO assessed and reclassified the incident correctly according to available information and issued appropriate notifications.

The provision and response of facilities and services were adequate to maintain the power system security over the course of the incident.

7 Conclusions

1. The A-H-T No.1 Line tripped due to earth switch being closed onto a live conductor. This was a switching error.
2. APDTS No.3 500 kV Busbar and No. 4 Transformer tripped due to a CBF operation on CB5500 at APDTS. This was an incorrect CBF operation and was caused by a design flaw in modification recently implemented by APD at APDTS. The modification has now been permanently removed.
3. A CBF trip signal, from APDTS to Tarrone, was not sent from APDTS. The reason for this trip signal failure is yet to be determined.
4. Macarthur wind farm was disconnected from the system by circuit breaker operations at Tarrone as a result of the ARPS operating at Heywood. This was caused by Point 3 above.
5. Power system security was maintained over the course of the incident.

8 Pending Actions

1. AusNet and APD to resolve the failed trip signal (Point 3 in Section 7) and notify AEMO of the resolution by 31 Oct 2014.
2. The AEMO reclassification as per Market Notice 45710 will remain in place until the cause of the failed trip signal resolved.

9 Recommendations

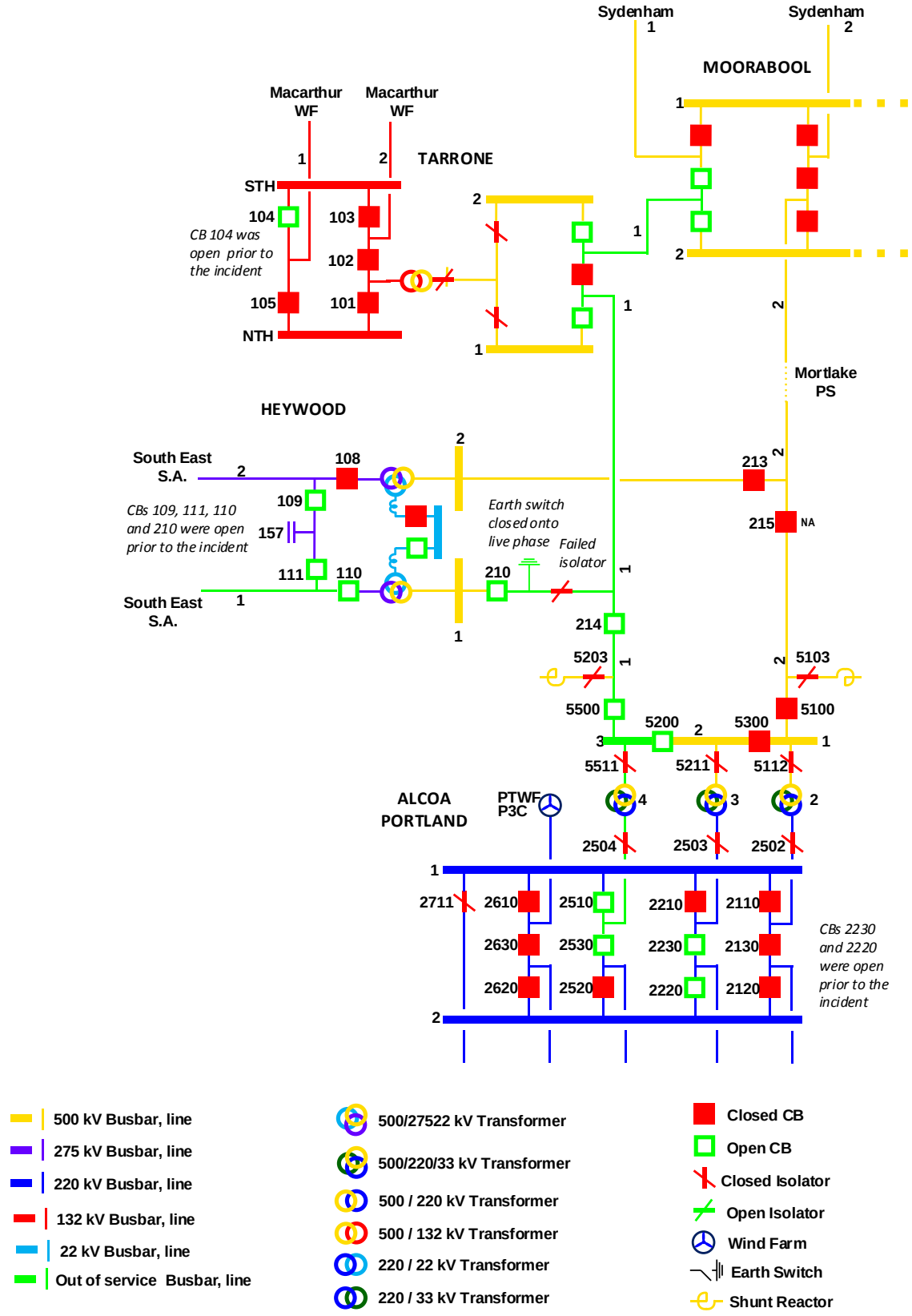
There are no recommendations arising from this review

[16] 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.

[17] Single phase-earth fault cleared within 50ms. This is within required timeframes specified in NER Clause S5.1a.8

Appendix 1 – System Diagram

The diagram show the status of the power system immediately after the incident.



Appendix 2 - Incident Event Log

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

Table 1 – Event Log

Time and Date	Event
0600 hrs 9 May 2014	Planned outage of M1 Transformer at Heywood
0600 hrs 9 May 2014	At Heywood CB 210 line side ROI opened. The white phase mechanism malfunctioned and the white phase remained closed
0647 hrs 9 May 2014	Earth switch closed. White phase closed onto live conductor causing a single phase earth fault
0647 hrs 9 May 2014	A-H-T No.1 Line tripped on white phase and CB214 opened on white phase
0647 hrs 9 May 2014	CBF on CB 5500 operated. Tripped APD No.3 500 kV Busbar and No. 4 Transformer
0647 hrs 9 May 2014	CB 214 at HYTS to opened on 3-phases upon receipt of a CBF trip signal from CB5500
0647 hrs 9 May 2014	CB5500 CBF trip signal from APDTS to Tarrone failed. A-H-T No.1 Line CBs at Tarrone remain closed
0647 hrs 9 May 2014	ARPS at Heywood detected a high voltage on A-H-T No.1 in the presence of a trip signal. ARPS operated and tripped M-T No.1 Line and islanded Macarthur Wind Farm. Generation at Macarthur wind farm reduced from 229 MW to 0 MW
0655 hrs 9 May 2014	AEMO invoked constraint sets V-HYTR, F-V-HYTR, V-MLTR, F-V-MLTR and V-MACARTHUR_ZERO
0740 hrs 9 May 2014	A-H-T No.1 Line and M-T No.1 Line returned to service
0745 hrs 9 May 2014	APD No.3 Busbar returned to service
0753 hrs 9 May 2014	Supply restored to Macarthur Wind Farm
0800 hrs 9 May 2014	AEMO revoked all constraint sets invoked after the non-credible contingency event
0809 hrs 9 May 2014	Market Notice 45697 issued informing the market of the non-credible contingency event
1139 hrs 9 May 2014	Market Notice 45701 issued informing the market that AEMO will not reclassify this event as a credible contingency
1910 hrs 9 May 2014	Market Notice 45702 issued informing the market that AEMO will reclassify this event as a credible contingency
1122 hrs 12 May 2014	Market Notice 45710 issued informing that AEMO will remove Portland Wind Farm from the reclassification
12 May 2014	APD identified and isolated the cause of the incorrect operation of CB5500 3 phase CBF timer

Appendix 3 - Overview of Anti-Resonance Protection Scheme (ARPS)

The ARPS at Heywood is designed to prevent high voltages being induced on a disconnected line conductor(s) on the A-H-T No. 1 500 kV transmission line.

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

- Capacitive coupling with the A-H-T No.2 500 kV transmission line, and
- The inductance of the A-H-T No.1 500 kV transmission line reactor located at APD.

The length of the line from APDTS to Tarrone is such that the resonant circuit forms. The objective of the APRS is change the length of the line to prevent a resonant circuit forming.

The ARPS is designed to open 500 kV CB214[18] at Heywood Terminal Station and divide the disconnected line into two sections. This reduces line capacitance and prevents a resonant circuit forming.

In the event that CB214 at Heywood Terminal Station fails to open, the CBF of the ARPS operates. The CBF operates if the CB contacts fail to open following a trip signal, and as a back-up, if a high voltage is detected on the Heywood-Tarrone section of the A-H-T No.1 line in the presence of a trip signal.

The CBF function disconnects No.1 500 kV transmission line from APDTS to Moorabool and configures the disconnected sections to form a single continuous line. This increases the capacitance of the disconnected line and prevents a resonant circuit from forming.

[18] CB214 is not used to clear faults on A-H-T No.1 500 kV transmission line.