TRIP OF BOTH 330 KV TRANSMISSION LINES SUPPLYING INGLEBURN SUBSTATION: 20 NOVEMBER 2015

REVIEWABLE OPERATING INCIDENT REPORT UNDER THE NATIONAL ELECTRICITY RULES

Published: August 2016

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of incident	1246 hrs Friday 20 November 2015
Region of incident	New South Wales
Affected regions	New South Wales
Event type	Loss of multiple transmission elements
Generation Impact	No generator was disconnected or limited as a result of this incident
Customer Load Impact	125 MW of customer load was disconnected as a result of this incident
Associated reports	Nil

IMPORTANT NOTICE

Purpose

AEMO has prepared this report in accordance with clause 4.8.15(c) of the National Electricity Rules, using information available as at the date of publication, unless otherwise specified.

Disclaimer

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1. OVERVIEW

This report relates to a reviewable operating incident[1] that occurred on Friday 20 November 2015 at Ingleburn substation (IS) in New South Wales. This incident involved the trip of the Wallerawang to Ingleburn 77, 330 kV transmission line (77 Line), and the Ingleburn to Sydney South 78, 330 kV transmission line (78 Line), resulting in the loss of 125MW of customer load.

As a reviewable operating incident, AEMO is required to assess power system security over the course of this incident, and 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] AEMO has concluded that:

1. The incident was caused by failure of a current transformer (CT) associated with a circuit breaker at Ingleburn sub-station.
2. The power system was not in a secure operating state during the incident.
3. The actions taken by AEMO, based on advice from TransGrid, were appropriate given the only action available to restore the power system to a secure operating state was pre-contingent load shedding.
4. AEMO has amended its assessment process for the planned outage combination of the Kangaroo Valley – Dapto and Kemps Creek – Sydney South lines by including this outage combination in the list of high impact outages.

This report is prepared in accordance with clause 4.8.15(c) of the National Electricity Rules (NER). It is based on information provided by TransGrid[3] and AEMO.

Australian Eastern Standard Time is used in this report.

2. THE INCIDENT

On Friday 20 November 2015 at 1246 hrs, 77 and 78 Lines tripped and as a result approximately 125MW of customer load was lost at IS.

TransGrid returned 78 Line to service at 1411 hrs the same day – 84 minutes after the trip – and customer load was fully restored by 1440 hrs - 114 minutes after the trip.

TransGrid returned 77 Line to service at 0001hrs on 22 November 2015.

The incident involved the tripping of two transmission lines, which as a simultaneous disruptive event, is classified under the NER as a non-credible contingency event[4].

See Appendix A for a power system diagram illustrating the incident and Appendix B for a chronological log of the incident.

[1] NER clause 4.8.15(a)(1)(i), as the event relates to a non-credible contingency event; and the AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.
[2] NER clause 4.8.15(b).
[3] TransGrid is the transmission network service provider in NSW
[4] NER clause 4.2.3(e).

3. TRANSGRID INVESTIGATION

TransGrid, as the Transmission Network Service Provider in NSW investigated this incident and provided the following information.

One phase of a 330kV CT associated with CB 772B at IS failed explosively. This resulted in the trip of 77 Line and Transformer No.2 at IS, leaving the load at IS fed via 78 Line and Transformer No.1. This is an expected outcome for this type of fault.

Three seconds later, 78 Line tripped due to a phase to earth fault resulting in the loss of all customer load at IS. The trip of 78 Line was due to the smoke/debris cloud from the initial fault on the CT at IS.

Subsequently 77 Line auto-reclosed at IS (CB 772A) and then tripped again and remained out of service. 78 Line auto-reclosed at Sydney South and remained closed. 78 Line remained open at Ingleburn because the auto-reclose function does not operate if there is no voltage at the IS end.

78 Line and No.1 Transformer were restored to service at 1411 hrs and all load at IS was restored by 1440 hrs.

77 Line was returned to service at 0001hrs on 22 November 2015 after the failed CT was isolated for repair.

On 9 December 2015 (18 days later), TransGrid replaced the failed CT.

This type of CT has an increased risk of failure as a small number have failed previously. Although the root cause is unknown, TransGrid has identified two possible causes:

- Quality control issues during manufacture, or
- A failure of the dielectric loss angle (DLA)[5] coupling equipment.

TransGrid has 126 CTs of this type in service. TransGrid has an asset management strategy in place to monitor their condition by taking oil samples at regular intervals. The results of the oil analysis are used to categorise the degree of deterioration within the CT insulation and hence determine if the CT is approaching the end of its serviceable life. Other factors such as physical condition, network criticality and safety are also used to develop the management strategy for these CTs. On the basis of this information, the CT population is categorised into four subcategories of high, medium and low priority risk, plus a residual risk category where the CTs continue to be monitored.

There were 16 CTs in the top three priority categories. The highest priority replacements, including the failed CT at Ingleburn were due for replacement in 2015-16 and have now all been replaced. The CTs in the remaining medium and low priority categories are included in a replacement program in the next regulatory period (2019-23). In response to any changes in oil sample results they may be replaced earlier than programmed.

To mitigate the DLA coupling issue TransGrid has ensured the DLA coupling equipment has been removed from all oil filled CTs in the network.

AEMO considers TransGrid's monitoring and replacement strategy is acceptable.

[5] Dielectric loss angle is a measurement of the integrity of electrical insulation.

4. POWER SYSTEM SECURITY

This section assesses how AEMO managed power system security over the course of this incident[6].

Coincident with the trips of 77 and 78 Lines, there were planned outages of the Kangaroo Valley – Dapto 18 and Kemps Creek – Sydney South 13 330kV transmission lines[7].

Immediately following the incident, at 1255 hrs, AEMO invoked constraint sets N-IGWW_77[8] and N-IGSS_78[9]. At 1335 hrs, after determining with off-line staff that it was appropriate, AEMO invoked constraint set N-X_DTKV_77_78_15M[10] due to the coincident planned outage of 18 Line.

As a result of these multiple outages AEMO's contingency analysis application could not solve for the contingent outage of the Sydney West – Liverpool 30 line or the Liverpool – Sydney North 12 line. This indicates that the power system was not in a secure operating state[11]. Due to the high loads in this area of the network at the time, the loss of either 12 or 30 Line would have resulted in low voltages in the Sydney South area.

Although AEMO invoked the constraint sets applicable for these line outages, there is effectively no generation solution available to reduce line loadings, and subsequently improve the voltage levels around the Sydney South area with this combination of outages.

AEMO discussed this issue with TransGrid. A number of potential solutions were identified including the switching of reactive devices at Sydney South and within the underlying 132kV network with a view to improving the voltage levels. Switching of reactive devices at Sydney South was not possible as pre-contingent voltage levels would be too high. A capacitor bank was switched into service at Bunnerong.

Subsequent analysis by TransGrid indicated that, while post-contingent voltage levels at Sydney South would still be low, they would be within acceptable limits.

13 Line was not available at the time, and the maximum recall time listed for this outage was 48 hours[12]. Had 13 Line been available for service, this would have provided support to Sydney South from Kemps Creek. Although the option of recalling 13 Line was not discussed by AEMO and TransGrid at the time, TransGrid did initiate the recall of this line, as at the time, the recall time was only two hours. TransGrid did not advise AEMO of this action. However after the return to service of 78 Line at 1411 hrs, TransGrid cancelled the recall of 13 Line before it had actually returned to service.

Apart from the recall of 13 Line, the only other available solution was for AEMO to instruct TransGrid to shed customer load pre-contingent. On the basis that TransGrid had advised AEMO that post-contingent voltage levels would be acceptable, AEMO did not instruct TransGrid to shed load.

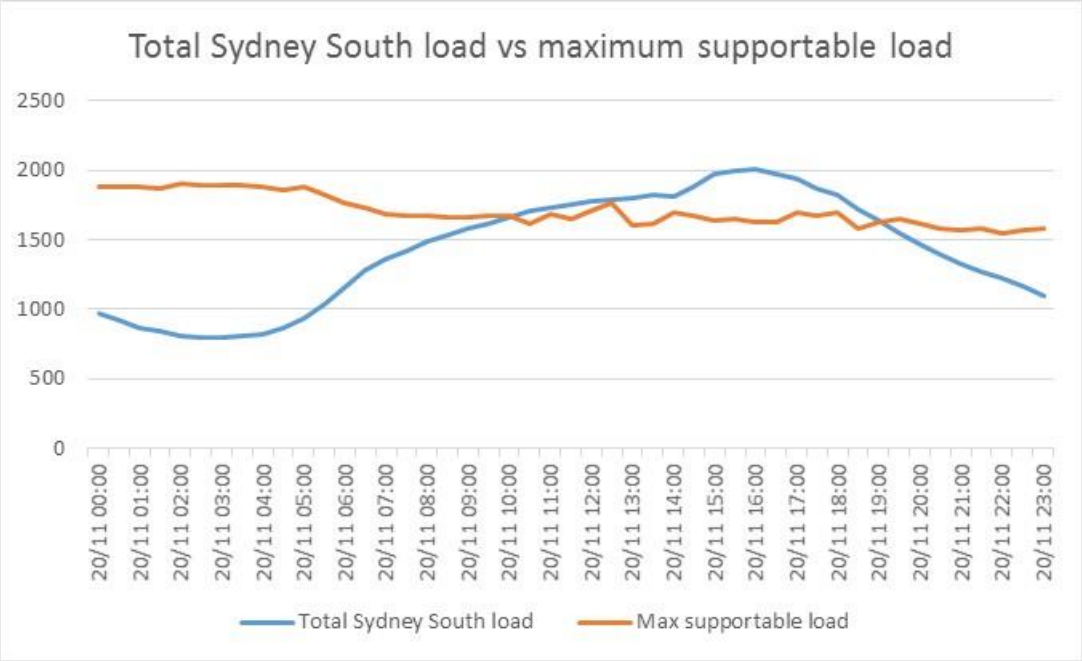
NER clause 4.2.4 defines when the power system is in a secure operating state (including the requirement that the power system is in a 'satisfactory operating state'). The definition of a 'satisfactory operating state' under NER clause 4.2.2 specifies that all voltage levels are within the limits provided by the relevant Network Service Provider. TransGrid, as part of their normal operating procedures advised AEMO that post-contingent voltages in the 330kv network around Sydney South area should not fall below 297kV (0.9pu).

[6] 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.
[7] 18 line outage from 0605hrs on 12/11/2015 to 1436hrs on 27/11/2015 with a 12 hour recall time. 13 line outage from 0600hrs on 17/11/2015 to 1500hrs on 28/11/2015 with a 48 hour recall.
[8] Constraint set required when the Ingleburn - Wallerawang 330 kV transmission line is out of service
[9] Constraint set required when the Ingleburn – Sydney South 330 kV transmission line is out of service
[10] Constraint set required when the Dapto – Kangaroo Valley 330 kV transmission line; and the Ingleburn - Wallerawang 330 kV transmission line or the Ingleburn – Sydney South 330 kV transmission line are out of service
[11] As defined by NER clause 4.2.4.
[12] Information supplied by TransGrid as part of the outage request in the Network Outage Scheduler.

After this event AEMO conducted analysis[13] based on the contingent loss of the Sydney West – Liverpool 30 Line[14] to determine the maximum supportable demand at Sydney South based on voltage levels of at least 297kV. The results, shown in Figure 1 indicate that post-contingent voltage levels in the area would have been below 297kV from around 1030 – 2000hrs[15], which indicates that based on the minimum voltage levels supplied by TransGrid, the power system would not have been in a secure operating state for this period.

With the restoration of 78 Line at 1411 hrs, all Ingleburn load would be fed only from Sydney South, potentially making the situation worse. However this was the only option available to restore the load at Ingleburn.

Figure 1 – Sydney South load



Discussion with TransGrid at the time indicated that voltages lower than 297kV would be acceptable and would be unlikely to result in a voltage collapse situation. Previous experience has shown this to be the case. It should be noted that with respect to voltage levels, there is no clear or exact delineation between acceptable and non-acceptable levels.

In summary, it is AEMO's view that although the power system was not in a secure operating state during the incident, the actions taken by AEMO and TransGrid staff at the time of the incident were prudent in that a voltage collapse situation was unlikely and the only option to improve the situation was pre-contingent load shedding.

Based on knowledge gained from this incident, AEMO will now consider the combined outage of 18 line and 13 line as a high impact outage under conditions of high demand[16].

4.1 Reclassification

After Line 78 was returned to service, AEMO then assessed whether or not to reclassify the event as a credible contingency. For this incident AEMO was satisfied that the cause had been identified and

[13] The analysis used a constant power load model. Loads around the Sydney South area are not constant power loads so analysis outcomes would be more conservative than actual outcomes. That is a greater voltage reduction would be seen in the study results than would actually occur.
[14] Worst case scenario as this would leave all Liverpool load fed from Sydney South
[15] This was from before the outage of 77 & 78 lines occurred and was confirmed by AEMO's contingency analysis application which showed intermittent violations for this period.
[16] Refer to SO_OP 3718 – Outage Assessment: http://www.aemo.com.au/Electricity/Policies-and-Procedures/System-Operating-Procedures/Outage-Assessment-SO_OP_3718

isolated, and that the incident was unlikely to reoccur. AEMO did not reclassify this event as a credible contingency event.

5. MARKET INFORMATION

AEMO is required by the NER and operating procedures to inform the market about incidents as they progress. This section assesses how AEMO informed the market[17] over the course of this incident.

For this incident, AEMO was required to inform the market on the following matters:

1. A non-credible contingency event - notify within two hours of the event.[18]

   AEMO issued Market Notice 50648 at 1308 hrs – 22 minutes after the event to notify market participants about the non-credible contingency and that approximately 125 MW disconnection of bulk electrical load had been observed by AEMO.

2. Updates to the non-credible contingency event – as information becomes available:[19]

   - AEMO issued Market Notice 50651 at 1513 hrs to notify market participants that Line 78 had returned to service, the bulk electrical load that was disconnected had been restored, and AEMO did not intend to reclassify this event as a credible contingency.
   - AEMO issued Market Notice 50653 at 1519 hrs to notify market participants that Line 78 had returned to service and constraint set N-IGSS_78 was revoked at 1425 hrs.

3. Constraints invoked with interconnector terms on the LHS.[20]

   AEMO issued Market Notice 50650 at 1322 hrs to notify participants about two invoked constraint sets (N_IGWW_77 and N-IGSS_78) that could impact interconnector flows on N-Q-MNSP1, NSW1-QLD1 and VIC1-NSW1.

Over the course of this incident AEMO issued appropriate, timely and sufficiently detailed market information.

6. CONCLUSIONS

AEMO has assessed this incident in accordance with clause 4.8.15(b) of the NER. In particular, AEMO has assessed the adequacy of the provision and response of facilities or services, and the appropriateness of actions taken to restore or maintain power system security.

AEMO has concluded that:

1. The incident was caused by the failure of a CT associated with a circuit breaker at Ingleburn sub-station.

   - This type of CT has a known increased risk of failure. TransGrid has replaced the CTs identified as at high risk of failure and has a monitoring and replacement program in place for the remaining CTs.

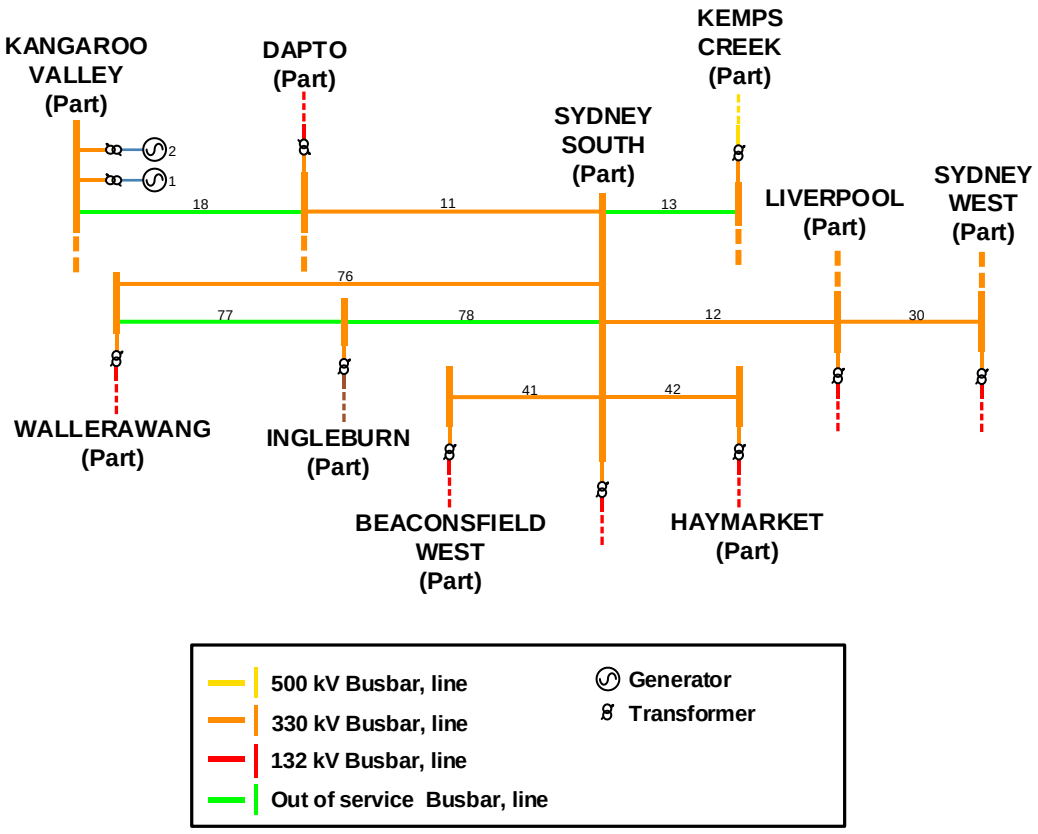
2. The power system was not in a secure operating state during the incident.

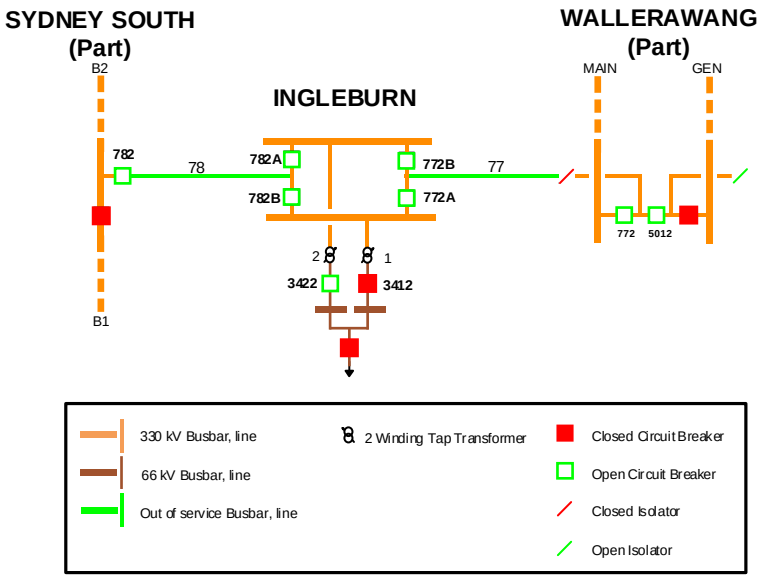
[17] AEMO generally informs the market about operating incidents as the progress by issuing Market Notices – see AEMO website
[18] AEMO is required to notify the Market of a non-credible contingency event within two hours of the event - AEMO, *Power System Security Guidelines,* Section 10.3.
[19] AEMO is required to notify the Market as it becomes aware of new and material information – NER clause 4.2.3A(d)
[20] For short term outage AEMO is required to notify the Market of variances to interconnector transfer limits AEMO, *Power System Security Guidelines,* Section 22

3. The actions taken by AEMO, based on advice from TransGrid, were appropriate given the only action available to restore the power system to a secure operating state was pre-contingent load shedding.
4. AEMO has amended its assessment process for the planned outage combination of the Kangaroo Valley – Dapto and Kemps Creek – Sydney South lines by including this outage combination in the list of high impact outages. This will ensure that suitable contingency plans to maintain or restore power system security are in place before these outages start.

APPENDIX A. – POWER SYSTEM DIAGRAM

The diagrams below show an overview of the relevant part of the power system and detail of the Ingleburn substation immediately after the event.





APPENDIX B. – INCIDENT EVENT LOG

Chronological Log of Incident

Time and Date	Event
12:46:45 Friday 20 Nov 2015	Line 77 opened at both ends and Ingleburn Transformer No.2 de-energised: • CBs 772B, 772A, 782A and 3422 at Ingleburn Substation opened • CBs 772 and 5012 at Wallerawang Substation opened,
12:46:48	Line 78 opened at both ends: • CB 782B at Ingleburn Substation opened and CB 782 at Sydney South Substation opened. Customer load at Ingleburn Substation disconnected
12:46:58	CB 772A at Ingleburn Substation closed but subsequently tripped again
12:47:04	CB 782 at Sydney South Substation closed successfully and remained closed (Line 78 was still open at Ingleburn end)
1255 hrs	AEMO invoked constraint sets N-IGWW_77 and N-IGSS_78
1308 hrs	AEMO issued Market Notice 50648. Notification of Non credible contingency event and approximately 125 MW of customer load disconnected
1335 hrs	AEMO invoked constraint set N-X_DTKV_77_78_15M
14:10:48	CB 782B at Ingleburn Substation closed (Line 78 returned to service)
14:11:24	CB 3412 at Ingleburn closed (Transformer No.1 energised)
1425 hrs	AEMO revoked constraint set N-IGSS_78
1513 hrs	AEMO issued Market Notice 50651. As an update to 50648. Notification that: • Line 78 returned to service • Customer load restored AEMO does not intend to reclassify this event as a credible contingency
1522 hrs	• AEMO issued Market Notice 50650. Notification of Constraints invoked N-IGSS_78 and N-IGWW_77
1519 hrs	AEMO issued Market Notice 50653 as an update to 50648. Notification that constraint N-IGSS_78 was revoked at 1425 hrs
1832 hrs	Transformer No.2 returned to service
23:57:38	CB 772A at Ingleburn Substation closed (Line 77 was still open at Wallerawang end)
00:01:15 Sunday 22 Nov 2015	CB 772 at Wallerawang Substation closed and Line 77 returned to service
00:01:55	CB 5012 at Wallerawang Substation closed
00:05:00	AEMO revoked constraints sets N-IGWW_77 and N-X_DTKV_77_78_15M
Wednesday 9 Dec 2015	CT replaced and in service