# TRIP OF TRANSMISSION LINES IN TASMANIA FOLLOWED BY THE LOSS OF BASSLINK ON 10 AND 16 DEC 2014, AND 23 FEB 2015

AN AEMO POWER SYSTEM OPERATING INCIDENT REPORT FOR THE NATIONAL ELECTRICITY MARKET

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

# IMPORTANT NOTICE

## Purpose

AEMO has prepared this document to provide information about this particular Power System Operating Incident.

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# VERSION RELEASE HISTORY

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# 1. OVERVIEW

This preliminary report reviews three similar power system operating incidents that occurred in Tasmania on 10 December 2014, 16 December 2014 and 23 February 2015. These incidents involved the trip of transmission lines in Tasmania followed by the trip of Basslink.[1]

AEMO is required to review and report on the two incidents in December 2014 as they comprised non-credible contingencies under the National Electricity Rules (NER).[2] The third event was included in the review because of its similar technical nature.

Specifically in relation to the reviewable incidents, 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[3] and to give details of the assessment and application of the reclassification criteria to each non-credible contingency event.[4]

AEMO's preliminary findings are that:

- The three faults on the 220kV system were cleared in accordance with the System Standard for fault clearance times.[5]
- The Basslink control and protection systems operated as designed.
- The unbalanced nature of the faults initiated commutation failure on the inverter at Georgetown, which is a normal occurrence on a temporary basis during faults in the Tasmanian AC system.
- The high voltage direct current (HVDC) link tripped because the commutation failures were sustained. The report also sets out the program for the next stage of detailed investigations.

Section 2 of this report describes the three incidents. Section 3 provides a technical assessment of the incidents, and Section 4 sets out AEMO's assessment of power system security over the course of the incidents. AEMO's preliminary conclusions are summarised in Section 5, together with the program for the next stage of detailed investigations.

This report is based on information provided by TasNetworks[6], Basslink Pty Ltd (Basslink)[7], and AEMO. National Electricity Market time (Australian Eastern Standard Time) is used in this report.

[1] Basslink is a direct current (DC) transmission connection (undersea cable) that electrically connects the Australian mainland to Tasmania.
[2] NER Clause 4.8.15(a)(1)(i) and AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.
[3] NER Clause 4.8.15 (b)
[4] NER Clause 4.8.15(a)
[5] NER Clause s5.1a.8
[6] TasNetworks is the Transmission Network Service Provider TNSP in Tasmania.
[7] Basslink Pty Ltd is the operator of the Basslink power cable that connects Victoria to Tasmania.

# 2. THE INCIDENTS

Three similar power system operating incidents occurred in Tasmania during December 2014 and February 2015. The three incidents involved the trip of 220 kV transmission lines, the trip of Basslink and the loss of customer load. The trip of Basslink for transmission faults elsewhere in Tasmania is an unexpected event and is identified in power system security terms normally as a non-credible event.[8]

See Appendix A for a power system diagram illustrating the incidents.

## 2.1 Trip of Waddamana–Lindisfarne No.2 Line and Basslink

On Wednesday 10 December 2014, at 1444 hrs, one phase of the Waddamana - Lindisfarne No.2 220 kV transmission line (WA-LF No.2 Line) was opened at each end in response to a fault condition. Single phase auto-reclose (SPAR) installed on this line then immediately auto-reclosed, successfully, to return the line to service. The trip event was due to a transitory fault.

During the event, Basslink tripped at the Tasmanian end 114ms after the fault. The trip of Basslink as a consequence of the fault on WA-LF N.2 line was unexpected. At the time Basslink was importing 443 MW into Tasmania.

As a result of the Basslink trip, the Frequency Control System Protection Scheme (FCSPS[9]) operated and disconnected 383 MW of customer load. This was an expected event designed to mitigate the impact on power system frequency caused by the loss of Basslink power transfer. The loss of customer load occurred in accordance with commercial arrangements. Customer load restoration began at 1537 hrs and was complete by 1617 hrs.

The WA-LF No.2 Line remained in service following the auto-reclose sequence, and Basslink returned to service at 1700 hrs the same day. Basslink investigated the trip of the interconnector and found that Basslink operated as per design.

TasNetworks investigated the fault event on the WA-LF No.2 line and found that the phase tripped as a result of a single phase to earth fault. The fault was cleared in 80ms, which is within the mandated timeframe[10], and successfully auto-reclosed via SPAR. TasNetworks considers that the fault event was most likely as a result of a lightning strike, as there was lightning activity in the area at the time. TasNetworks patrolled the line by air the following day but did not identify an obvious fault location.

## 2.2 Trip of Gordon – Chapel Street No.1 and No. 2 lines and Basslink

On Tuesday 16 December 2014 at 0746 hrs, one phase in each of the Gordon – Chapel Street No.1 and No.2 220 kV transmission lines (GO-CS Lines) tripped as a result of a single phase fault. Each phase was tripped at the Gordon and Chapel Street ends and both phases auto-reclosed successfully. The trip was the result of a transitory fault and the auto-reclose was an expected event.

[8] NER Clause 4.2.3 – Credible and non-credible events: AEMO Power system Security Guidelines Section 10 – Definition of a non-credible event.

[9] The FCSPS is designed to disconnect a predetermined load for a trip of Basslink when it is importing into Tasmania. This operation is required to maintain power system frequency following the trip of Basslink. Without the FCSPS the frequency in Tasmania would fall below the minimum operating standard following a Basslink (importing) trip.

[10] NER Schedule 5.1a System Standards Clause S5.1a.8 – Fault clearance times.

During the event, Basslink tripped at the Tasmanian end 112ms after the fault. The trip of Basslink as a consequence of the effect of the faults on the GO-CS lines was unexpected. At the time, Basslink was importing 469MW into Tasmania.

As a result of the Basslink trip, the FCSPS operated and disconnected 402 MW of customer load. This was an expected event for the reasons described in Section 2.1. The loss of customer load occurred in accordance with commercial arrangements. Customer load restoration began at 0805 hrs and was complete by 0908 hrs.

Basslink investigated the trip of the interconnector and found that Basslink operated as per design. Basslink was returned to service at 0900 hrs the same day.

TasNetworks investigated the trip of the GO-CS Lines and found that the faulted phases tripped as a result of single phase earth faults. The faults was cleared in 80ms which is within the mandated timeframe.  TasNetworks considers that the line fault events were most likely a result of a lightning strike, as there was lightning activity in the area of the line at the time.

## 2.3 Trip of Gordon – Chapel Street No. 2 Line and Basslink

On Monday 23 February 2015 at 0054 hrs, the GO-CS No.2 transmission line tripped. The line tripped as a result of a phase to phase fault. As TasNetworks does not apply auto-reclose to multi-phase faults, all three phases were opened, thus removing the line from service.

During the event, Basslink then tripped at the Tasmanian end 105ms after the fault. The trip of Basslink as a consequence of the fault on the GO-CS Line was an expected event, given that this type of incident had been classified as a credible contingency following the incident on 16 December 2014.

As a result of the Basslink trip, the FCSPS operated and disconnected 485 MW of customer load. This was an expected event for the reasons described previously in Section 2.1. The loss of customer load occurred in accordance with commercial arrangements. Customer load restoration began at 0115 hrs and was complete by 0200 hrs.

Basslink returned to service at 0220 hrs, 86 minutes after it tripped, while the GO-CS No. 2 Line was returned to service at 0750 hrs the same day.

TasNetworks investigated this incident and found that smoke ingress to the transmission line easement from a nearby bushfire was the most probable explanation for the fault event. The bushfire had been started the previous day by lightning. The fault was cleared within 120ms which is within the mandated timeframe.   The GO-CS circuits had experienced single phase transitory faults the previous evening.

## 2.4 Recent Transmission faults that did not trip Basslink

Between 10 Dec 2014 and 23 February 2015 there were three transmission faults on the Tasmanian 220 kV system that did not result in a Basslink trip.  These three trips were as follows, and were all most likely caused by lightning:

1. On 16 December 2015 at 1208 hrs, the GO-CS No.2 Line tripped and auto-reclosed.
2. On 22 February 2015 at 1732 hrs, the GO-CS No.1 and 2 Lines tripped and auto-reclosed on a single phase. At the same time Gordon unit 1 (96 MW) and unit 2 (97 MW) tripped.

3. On 22 February 2015 at 2013 hrs, the GO-CS No.2 line tripped. The line was manually reclosed.

# 3. TECHNICAL REVIEW

TasNetworks and Basslink, as operators of the Tasmanian transmission system and Basslink HVDC[11] interconnector respectively, assessed the network issue which was impacting on network users in Tasmania including Basslink. The section outlines the main points of their findings as presented to AEMO.

Basslink and TasNetworks agree that the faults created AC wave distortion, caused primarily by phase shifting. The distortion on the AC system was still present when Basslink attempted to re-commutate consistent with the controls of a line commutated converter. This AC distortion resulted in re-commutation failure, which in turn tripped Basslink for each of the three incidents.

Basslink and TasNetworks also agree that this issue is only relevant to the inverter of the HVDC when Tasmania is importing. The likelihood of AC wave distortion on the Victorian network, when the mainland is importing, is practically nil. This is because the strength of the mainland network enables it to maintain the AC waveform, under fault conditions at the Basslink connection point.

See Supporting Document 1 for the joint TasNetworks and Basslink Pty Ltd report assessing commutation failure.

## 3.1 Commutation Failure

A HVDC link is a DC transmission system which transfers power between two AC systems. It basically consists of:

1. A rectifier that converts AC power into DC power at one end.
2. An inverter that converts DC power to AC power at the other end.
3. A DC transmission line or cable which transmits DC power from the rectifier end to the inverter end.

The inverter converts DC power to AC power by co-ordinated switching of high current semi-conductor devices, known as thyristors, to transfer conductance between AC phases. The process is known as “commutation”.

The process of turning off a thyristor requires a negative voltage across the thyristor for a certain duration of time. This time period is known as the extinction angle.[12] If this extinction angle becomes too small, then this could result in unwanted re-conduction of the thyristor. This causes a commutation failure where two thyristors connecting different phases are conducting at the same time, effectively creating a short circuit between the phases. Such a condition can only be tolerated for a short period.

AC fault conditions in the network to which the inverter is connected can cause a reduction in the extinction angle due to:

[11] For general information about HVDC links see: http://www.energy.siemens.com/hq/en/power-transmission/hvdc/hvdc-classic/
[12] For further details refer Supporting Document 1.

1. A voltage magnitude depression.
2. A voltage phase angle shift (advance).

Balanced AC faults (that is, unusual three phase faults) will result in a voltage magnitude depression only, and will have less of an impact on the extinction angle.

Unbalanced AC faults (that is, single phase or double phase faults) are likely to cause the greatest reduction of extinction angle. This is because of the potentially large voltage phase shift, combined with a voltage magnitude depression. These levels of voltage dip and phase shift are determined by the relative values of the fault impedance and source impedance as seen at the HVDC link inverter terminal. The degree of phase shift caused during unbalanced AC faults is highly variable. A high impedance single phase fault may cause only minor phase shift, whereas a low impedance line-line fault could cause a maximum theoretical phase shift of $60^{O}$.

The ability of Basslink, a line commutated HVDC transmission link, to re-commutate after an AC transmission fault at the inverter end depends upon a number of factors. However, successful re-commutation is more difficult for higher levels of voltage depression and phase angle shift as is more commonly seen in weaker AC systems.

## 3.2 Industry Practice

Commutation failure on a HVDC link such as Basslink is considered a normal occurrence for AC system fault conditions at the inverter end. Modern HVDC interconnectors are designed to operate and respond during AC faults to minimise network separation events.

Consider the following discussion from a CIGRE Working Group Report (Commutation Failures Causes and Consequences, November 1995):

> "… a properly designed HVDC system will recover very fast and the power transmission capability will be restored and single commutation failures do not usually incur any adverse consequences in the connected a.c. systems. If the disturbance in the a.c. system is persistent, the d.c. power might be limited depending upon the severity of the disturbance."
>
> "After the first one or two commutation failures, there is a fundamental inherent ability of modern HVDC systems and their controls to quickly recover commutation and provide some power injection, even for quite low a.c. voltages that may exist prior to fault clearing. This recovery is most difficult and critical for a very weak or highly distortable a.c. system."

Further industry literature and practice[13] demonstrate that:

- Temporary commutation failure at inverter end of the HVDC link is an expected outcome under certain AC fault conditions.

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[13] References:

1. CIGRE Working Group Report 14: Commutation Failures Causes and Consequences, (November 1995)
2. Davies M, Kolz A, Kuhn M, Monkhouse D, Strauss J: Latest Control and protection Innovations Applied to the Basslink HVDC Interconnector.
3. Khatir M, Zidi SA, Hadjeri S, Fellah MK, Daou O: Effect of the DC Control on Recovery from Commutation Failures in as HVDC Inverter Feeding a Weak AC Network, Journal of Electrical Engineering, Vol 58, No. 4, 2007.
4. Khatir M, Zidi SA, Hadjeri S, Fellah MK: Analysis of Recovery from Commutation Failures in an HVDC Inverter connected to a weak Receiving AC System.

- HVDC links are designed to quickly recover from such commutation failures so as to avoid loss of the HVDC link. However such a recovery is more difficult when the AC system is weak.

## 3.3 Tasmanian Transmission Faults and Coincident Basslink Trips

Between 2006 and 23 February 2015 there have been 70 significant transmission network events that have occurred when Basslink was importing to Tasmania (see Supporting Document 2). The three incidents considered in this report are the only events where a fault on the Tasmanian AC system has led to loss of Basslink. AEMO has observed that for each of the three incidents:

1. Synchronous generation was geographically remote to Basslink inverter terminal.
2. The AC network events were remote from the Basslink inverter terminal.

# 4. POWER SYSTEM SECURITY

AEMO investigated power system security over the course of the three incidents.[14] This section sets out AEMO's findings.

## 4.1 Trip of WA-LF No.2 line and Basslink on 10 December 2015

Immediately following the incident, at 1444 hrs, the power system was in a secure state.

AEMO was aware of the Basslink trip initially, but not of the WA-LF No.2 Line trip and reclose.[15] AEMO issued Market Notice (MN) 47206 at 1455 hrs to notify the market of the Basslink trip, and TasNetworks commenced restoring load at 1537 hrs.

At 1541 hrs TasNetworks notified AEMO of the WA-LF No.2 Line trip and auto-reclose, and at 1602 hrs Basslink notified AEMO that the Basslink trip was a commutation failure and that it occurred at the same time as the WA-LF No.2 Line trip.

At 1712 hrs AEMO issued MN 47209 to notify the market of the simultaneous trip of Basslink and the WA-LF No.2 line. AEMO then reclassified the incident as a credible contingency. AEMO considered, based on the information available at the time, that the incident could reoccur. AEMO issued Market Notice 47210 to notify the market of the reclassification. AEMO limited the reclassification to the WA-LF No. 2 Line and Basslink, as there was no previous history of Basslink tripping as a result of Tasmanian transmission faults.

Over the course of this incident the power system remained in a secure state. Power system frequency[16] and voltage[17] remained within limits and the fault was cleared within required timeframes.[18] AEMO issued appropriate notifications and based upon information available at that time, correctly assessed the incident and reclassified the incident as a credible contingency.

## 4.2 Trip of GO-CS Lines and Basslink on 16 December 2015

Immediately following the incident, at 0746 hrs, the power system was in a secure state.

At 0756 hrs Basslink operators notified AEMO that there was a single phase network voltage depression at the same time as the Basslink trip. At 0820 hrs TasNetworks notified AEMO that, at the same time that Basslink tripped, the GO-CS Lines had tripped at the Gordon end and auto-reclosed. At 0900 Basslink returned to service.

At 0938 hrs AEMO issued MN 47307 to notify the market of the simultaneous trip of Basslink and the GO-CS No.1 and 2 lines and that the incident was a non-credible contingency event.

The following sub-sections explain further actions that AEMO implemented as a result of the incident.

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[14] 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.

[15] The trip and reclose occurred between data refresh cycles on the SCADA system.

[16] Operating Frequency Tolerance Band specified in AEMC Reliability Panel Frequency Operating Standards.

[17] NER Schedule 5.1a System Standards Clause S5.1a.4 - Power frequency voltage

[18] NER Schedule 5.1a System Standards Clause S5.1a.8 – Fault clearance times

### 4.2.1 Gordon – Chapel Street lines deemed vulnerable to lightning

At the time of the incident there was lightning in the vicinity of the GO-CS lines. AEMO considered that the GO-CS lines most likely tripped due to a fault caused by a lightning strike. AEMO then, in accordance with Power System Security guidelines (SO_OP_3715) deemed the GO-CS lines to be vulnerable.[19] AEMO notified the market of this decision in MN 47307. This action meant that in future if AEMO observed lightning in the vicinity of these lines then the simultaneous loss of both lines would be reclassified as a credible contingency.

### 4.2.2 Gordon – Chapel Street lines reclassified due to lightning

Subsequently at 1134 hrs the same day, AEMO reclassified the GO-CS Lines as a credible contingency due to lightning in the vicinity of the lines (MN47312). At 1354 AEMO cancelled this reclassification (MN47322) as there was no longer lightning in the region. The lines did not trip due to lightning during this period.

### 4.2.3 Reclassification of Basslink and Tasmanian 220 kV lines

At 1238 hrs AEMO issued MN47315 to reclassify the trip of Basslink with any transmission line trip in Tasmania as a credible contingency. This reclassification modified the one issued on 10 Dec (MN47209). The reason for the modification was that this was the second transmission event that had tripped Basslink for which the root cause remained unknown. AEMO considered, based upon the information available at the time, that such an event could reoccur in conjunction with a fault on any 220 kV transmission line in Tasmania. This meant that:

- A fault on a radial line connecting a large generating unit to the network could result in the loss of this generating unit and Basslink. This meant that the combined loss would need to be treated as a credible contingency event, requiring a large amount of raise frequency control ancillary services to be sourced solely within the Tasmanian region.
- A fault on the radial line connecting two Comalco potlines to the network could result in the loss of these two potlines and Basslink. This meant that the combined loss would need to be treated as a credible contingency event requiring a large amount of lower frequency control ancillary services to be sourced solely within the Tasmanian region.

### 4.2.4 Direction to switch off the Basslink Frequency Controller

If Basslink tripped as a result of a transmission fault, then Basslink would then not be available to transfer Frequency Control Ancillary Services (FCAS) from the mainland (as discussed above). As AEMO had deemed this scenario a credible contingency, Tasmanian FCAS requirements now needed to be sourced from Tasmania only. To implement this action, AEMO directed Basslink, at 1217 hrs, to disable the Basslink Frequency Controller.[20]

When the Basslink controller is disabled the National Electricity Market Dispatch Engine (NEMDE) sources Tasmanian FCAS requirements locally (from Tasmania).

An alternative method of sourcing Tasmanian FCAS requirements locally would have been to invoke constraints. At the time AEMO considered that the time required to construct and test such a large number of constraints was impractical as a short term measure, compared with the relative simplicity of disabling the Basslink Frequency Controller.

[19] Vulnerable transmission lines are double circuit transmission lines which are classified by AEMO as reasonably likely to trip on both circuits simultaneously as a result of lightning. See AEMO SO_OP 3715 Power System Security Guidelines.

[20] Basslink Frequency Controller enables Basslink to respond to changes in frequency in both the mainland and Tasmanian AC systems.

The Basslink Frequency Controller remained out of service until 1317 hrs on Friday 19 December, when modified sets of constraint equations became available. During this period Tasmanian frequency was controlled entirely by FCAS services within Tasmania, which is an unusual condition. The Tasmanian frequency varied more than usual in the period:

- The frequency was outside of the normal operating frequency band (49.85 to 50.15 Hz) 7% of the time. The Tasmanian Frequency Operating Standard required the frequency not to move outside of this band for more than 1% of the time over a 30 day period.
- The frequency was outside of the normal operating frequency excursion band (49.75 to 50.25 Hz) 0.4% of the time. The Frequency Operating Standard requires the frequency to remain within this band except during contingency events.

Further investigations are being undertaken on the performance of the system under similar conditions. A planned outage of Basslink in May 2015 has provided an opportunity for these investigations.

### 4.2.5 Violating Tasmanian FCAS constraints

Commencing 1225 hrs, following the Basslink frequency controller being disabled, Tasmanian FCAS constraint violated (F_T+CSGO_T6_R6[21]). The constraint violated because insufficient Raise 6 Second FCAS (R6) was available in Tasmania in the event that both the GO-CS Lines and Basslink tripped (following the reclassification of the GO-CS lines due to lightning).

Contributing factors to the violation were that:

- Tasmanian R6 requirements were sourced in Tasmanian due to disabled Basslink Frequency Controller.
- Both GO-CS Lines reclassified as single credible contingency, due to lightning in the region.
- Gordon Power Station, the largest power station in Tasmania, could not be used for F6 as it would be stranded in the event that the GO-CS Lines tripped.

### 4.2.6 AEMO direction to Gordon Power Station

AEMO attempted to resolve the violating constraints by consulting with Hydro-Tasmania, with a view to rebalancing Tasmanian generation to relieve the constraints. However no effective solution could be identified in the short term. At 1320 hrs AEMO directed[22] Hydro-Tasmania to reduce generation at Gordon Power Station (MN47319). By 1330 hrs violating constraints had ceased. The constraint violated for 13 dispatch intervals over a period of 1 hour 15 minutes. AEMO cancelled the direction at 1345 hrs.

### 4.2.7 Cancelation of reclassification of GO-CS lines due to lightning

At 1354 hrs AEMO cancelled the reclassification issued at 1154 hrs as there was no longer lightning activity in the vicinity of the GO-CS lines.

### 4.2.8 Cancellation of GO-CS lines as vulnerable line

At 1411 hrs AEMO cancelled the decision to deem the CO-GS Lines as vulnerable to lightning.

[21] Constraint F_T+CSGO_T6_R6 sets the Raise Six Second frequency requirement for the loss of the GO-CS lines.
[22] See NER Clause 4.8.9

Following the GO-CS line trips, detailed information about the trips was not available. AEMO was thus unaware that the trips and recloses had been SPAR operations. AEMO classified the GO-CS Lines as vulnerable, assuming incorrectly that the trips had been three phase trip and reclose. Classification of the lines as vulnerable in turn led to the GO-CS lines being reclassified as a credible contingency due to lightning (see Section 4.2.2), constraint violations (see Section 4.2.5), and a direction being issued to Gordon Power Station (see Section 4.2.6). AEMO is preparing a separate report on the direction and surrounding circumstances as required under NER Clause 3.13.6A.

TasNetworks notified AEMO at 1300 hrs that both the GO-CS lines had tripped and reclosed on single phases only. The Power System Security Guidelines (SO_OP 3715) state that SPAR operation does not require a line to be classified as vulnerable to lightning. AEMO cancelled the vulnerable classification at 1411hrs.

### 4.2.9 Amendments to Reclassification of Basslink and Transmission lines in Tasmania

Following the decision to disable the Basslink frequency controller (at 1217 hrs on 16 December), AEMO implemented various amendments to the reclassification to better target the intent of the reclassification.

#### Amendment 1

On 22 December 2014, AEMO amended the reclassification so that it applied only when Basslink was flowing from Victoria into Tasmania. TasNetworks had notified AEMO that the risk of a Basslink trip for a transmission fault in Tasmania applied only for imports into Tasmania. For exports, from Tasmania to Victoria, there was no known risk of trip related to faults on the Tasmanian transmission network.

This action enabled FCAS for Tasmanian contingencies to be sourced NEM-wide when Basslink is exporting from Tasmania to Victoria.

#### Amendment 2

On 8 January 2015, AEMO enabled FCAS regulation services to be sourced NEM-wide regardless of the direction of flow on Basslink. AEMO considered that in the event of a Basslink trip only FCAS contingency services would be required; as FCAS regulation services are not contingency services then they could be sourced NEM-wide at all times.

#### Amendment 3

On 22 January 2015, TasNetworks notified AEMO that a fault on the George Town to Comalco 220 kV transmission lines (GT-CO Lines) would not trip Basslink. This was because of a special feature in the Basslink protection system, which blocks the tripping of Basslink due to extended commutation failure if the AC voltage level at the inverter connection point falls below 30% of nominal voltage. This would be the case for any faults on the AC system close to Basslink's point of connection at George Town SS.

This enabled FCAS lower services to again be sourced NEM-wide. The loss of the two Comalco potlines radial on the single line is the largest credible contingency load loss event in Tasmania. The remaining single contingency loads are small and would not significantly impact frequency upon a fault that subsequently tripped Basslink.

## 4.3 Trip of GO-CS No.2 Line and Basslink on 23 February 2015

As a result of the incident, the FCSPS had operated as designed to maintain power system frequency in Tasmania. Immediately following the incident AEMO invoked constraint sets (F-T-CSGO and T-CSGO) to maintain power system security while the GO-CS No.2 Line was out of service.

From 0125 hrs constraints F_T+CSGO_TG_R6, F_T+CSGO_TG_R60 started to violate. These constraints violated due to insufficient FCAS Raise six second service offers and FCAS Raise sixty second offers. The increased FCAS requirements were needed for the contingent trip of GO-CS No. 1 transmission line and thereby Gordon Power Station.

At 0145 hrs AEMO directed Gordon Power Station to reduce generation to mitigate the increased FCAS requirement. The constraints intermittently violated until 0220 when the violations ceased and AEMO cancelled the direction.

Over the course of this incident the power system was either in a secure state or appropriately returned to a secure state. AEMO did not need to reclassify this incident as a credible contingency because the incident had already been reclassified as a credible contingency on 16 Dec 2015.

# 5. CONCLUSION

## 5.1. Preliminary Findings

The preliminary findings are that

- The three faults on the 220kV system were cleared in accordance with the System Standard, and based upon information provided by TasNetworks, network protection and control systems operated as designed.
- Based upon information provided by Basslink, the Basslink control and protection systems operated as designed.
- The unbalanced nature of the faults initiated commutation failure on the inverter at George Town, which was is a normal occurrence on a temporary basis during faults in the Tasmanian AC system.
- The high voltage direct current (HVDC) link tripped because multiple commutation failures were sustained. This has not occurred previously for Basslink.[23] HVDC links are designed to quickly recover from commutation failures so as to avoid loss of the HVDC link. However such a recovery is more difficult when the AC system is weak.

## 5.2. Consideration of additional short term measures

Two further possible short term measures to improve reliability of supply have been considered. These are:

1. Increase commitment of generating units in vicinity of George Town, in either generation or synchronous condenser mode to reduce voltage fluctuations when faults occur. This could reduce but not eliminate the likelihood of Basslink tripping due to faults on the a.c. system.
2. Reduce import on Basslink whenever there is lightning in the vicinity of the Tasmanian 220kV network and sections of the 110kV Network remote from George Town. This would reduce the impact of a Basslink trip in terms of load interrupted.

Both options could also have a significant impact on market and commercial arrangements. AEMO considers that such intervention is not justified and may increase costs to the market.

The current measures to reclassify certain contingencies are maintaining power system security but it is recognised that they present an increased risk of temporary disruptions for major industrial customers in Tasmania. AEMO thus considers these existing measures to be short term measures only, and a longer term solution to the underlying issues is required.

## 5.3. Program for detailed investigation

AEMO, in conjunction with TasNetworks, is undertaking detailed investigation using electromagnetic transient models to better understand the reasons for these recent failures.

The program is below. The expected completion dates assume timely provision of network information and no complications arising from AEMO's use of the model data.

[23] A review of the operational history of Basslink has shown that that ,prior to these recent events, there were at least 54 faults on the ac system which led to temporary commutations failures but that none of these resulted in loss of the HVDC link.

| Action | Details | Due |
|---|---|---|
| Data acquisition | Obtain additional power system modelling information from Basslink and TasNetworks | 5 May 2015 |
| Model accuracy | Verify the accuracy of the Tasmanian and Basslink Interconnector special software computer model by replicating the system events of December and February and overlaying the results with measurements of the actual events. | 22 May 2015 |
| Scoping | a) To reduce working time, conduct scoping studies using AEMO's standard network model to identify generation scenarios and Tasmanian contingencies that will result in the largest voltage angle shift with the transmission voltage at Basslink remaining above 30% nominal. | 8 May 2015 |
| Non-network solution | b) Replicate scoped set of critical studies using Basslink and TasNetworks special models to identify potential non-network solution i.e. generation dispatch solution | 9 June 2015 |
| Draft Report | c) Summarise results of the analysis and report whether or not a non-network solution exist that will prevent further trips to the Basslink Interconnector. | 26 June 2015 |

## 5.4. Longer term solutions

The ultimate aim of these investigations will be to propose options for a long-term solution. Development of these options will need to be based upon the results of the modelling. However indications at this early stage are that:

- Measures that reduce the likelihood of voltage fluctuations initiating commutation failure will only reduce the probability of such incidents to a limited extent and so are not likely represent a comprehensive solution.
- Measures that reduce the likelihood of commutation failure being sustained long enough to result in the loss of the link are more likely to achieve a comprehensive solution.

## 5.5. Incorrect reclassification

The following steps have been undertaken to reduce the risk of a reclassification based upon incorrect assumptions, as occurred on 16 December 2014 for the GO-CS transmission lines:

- Operations staff now actively clarify operational information when advised of an auto-reclose power system incident.
- SO_OP_3715 – Power System Security Guidelines has been updated to more prominently indicate that only simultaneous three phase trips of both circuits on a double circuit transmission line during a lightning storm are to be considered as a trigger to declare the line as vulnerable to lightning.
- Operations staff have undertaken a training program based on this scenario.

# LIST OF SUPPORTING DOCUMENTS

| Reference | Title or description |
|---|---|
| **Supporting Document 1** | TasNetworks and Basslink Pty Ltd report assessing commutation failure. |
| **Supporting Document 2** | Spreadsheet: Transmission network events that have resulted in commutation failures when Basslink was importing to Tasmania |

# ABBREVIATIONS

| Abbreviation | Term |
|---|---|
| AC | Alternating Current |
| AEMO | Australian Energy Market Operator |
| CB | Circuit Breaker |
| DC | Direct Current |
| FCAS | Frequency Control Ancillary Services |
| FCSPS | Frequency Control System Protection Scheme |
| GO-CS | Gordon to Chapel Street 220 kV transmission line (two lines No. 1 and No. 2) |
| HVDC link | High Voltage Direct Current Link |
| kV | Kilovolt |
| WA-LF | Waddamana to Lindisfarne 220 kV transmission line |
| MN | Market Notice |
| MW | Megawatt |
| NER | National Electricity Rules |
| SCADA | Supervisory Control and Data Acquisition |
| SPAR | Single Phase Auto Reclose |
| WA-LF | Waddamana to Lindisfarne 220kV transmission line |

# APPENDIX A. POWER SYSTEM DIAGRAM

Power system diagram showing part of the Tasmanian 220 kV transmission system and the location on the system of the three faults.