# FINAL REPORT – LOAD SHEDDING IN TASMANIA ON 20 DECEMBER 2016

## REVIEWABLE OPERATING INCIDENT REPORT FOR THE NATIONAL ELECTRICITY MARKET

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

# 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.

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# 1. OVERVIEW

This is AEMO's final report about a reviewable operating incident[1] that occurred on 20 December 2016 in Tasmania. At 0932 hrs on 20 December 2016, an outage of both Sheffield to George Town (SH–GT) 220 kilovolt (kV) transmission lines in Tasmania resulted in the loss of approximately 217 megawatts (MW) of generation and 170 MW of load in Tasmania.

AEMO published a preliminary report on 22 December 2016.[2] This final report provides:

- Additional information on the cause of the trip of the SH-GT1 and SH-GT2 transmission lines and the operation of the backup network control system protection scheme.
- Further analysis of frequency in Tasmania and the delivery of fast raise frequency control ancillary service (FCAS) by generating units in Tasmania.

As this was 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.[3]

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 TasNetworks and Hydro Tasmania and from AEMO systems.

AEMO has concluded that:

- The simultaneous trip of both SH–GT 220 kV lines was a non-credible contingency[4] and was the result of the incorrect operation of protection relays during planned work by TasNetworks on a communications bearer.
- The power system was not in a satisfactory operating state[5] for seven minutes.
- The power system was not in a secure operating state[6] for 15 minutes.
- The under frequency load shedding (UFLS) scheme, backup Network Control System Protection System (NCSPS)[7], and Basslink frequency controller operated as designed.

AEMO gave permission to restore all load in Tasmania at 0949 hrs, 17 minutes after the event.

There was no material impact on other NEM regions as a result of this event.

Australian Eastern Standard Time (AEST) is used in this report. In December, the local time in Tasmania is AEST plus one hour.

# 2. PRE-EVENT CONDITIONS

Immediately prior to the event, all transmission equipment in Tasmania was in service and the power system in Tasmania was in a secure operating state.

The operational demand in Tasmania immediately prior to the event was approximately 1,052 MW.

Generation in Tasmania was 1,210 MW, with 145 MW transfer from Tasmania to Victoria on the Basslink interconnector. Of the 1,210 MW of generation, 217 MW was supplied by the generating units connected to the Sheffield substation.

[1] See NER clause 4.8.15.
[2] AEMO. *Preliminary Report – Load Shedding in Tasmania on 20 December 2016. A preliminary operating incident report for the National Electricity Market – information as at 0900 hrs, Thursday 22 December 2016*. Available at: http://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2016/Preliminary-Report---Load-Shedding-TAS.pdf.
[3] See NER clause 4.8.15(b).
[4] See NER clause 4.2.3
[5] See NER clause 4.2.2
[6] See NER clause 4.2.4
[7] Refer to Appendix C for a description of the NCSPS.

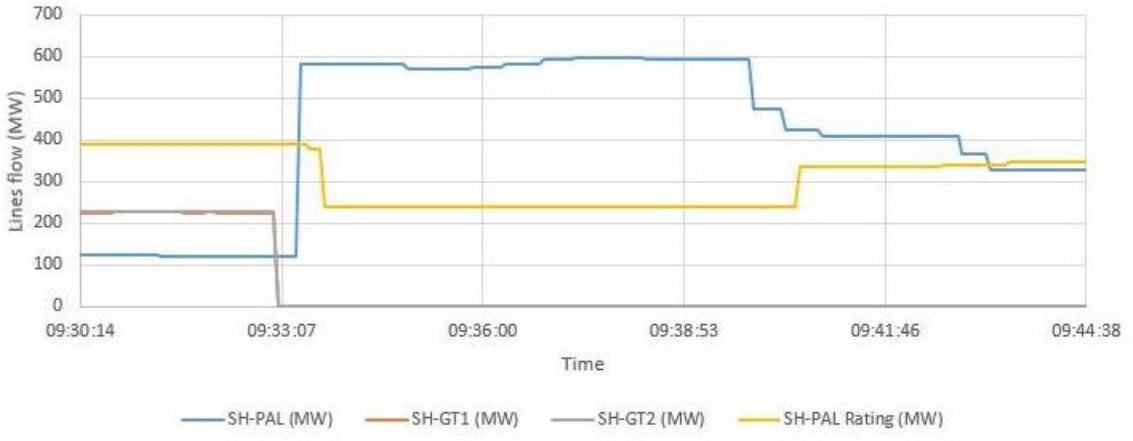
# 3. INCIDENT DETAILS

At 0932 hrs, both of the SH–GT 220 kV transmission lines tripped simultaneously, during work by TasNetworks to commission a new communications link.

There was no actual fault on either of the SH–GT lines.

The loss of these transmission lines resulted in the flow across the Sheffield to Palmerston (SH–PM) 220 kV transmission line increasing from 123 MW to 590 MW (150% of rated capacity), as shown in Figure 1.

**Figure 1 MW flow on SH–GT and SH–PM lines**




At 0939 hrs, TasNetworks attempted to restore the SH–GT2 line from the Sheffield end. When the circuit breaker was closed, generating units at Lemonthyme/Wilmot, Cethana, Fisher, and Devils Gate (Mersey Forth generation) tripped, resulting in a loss of 217 MW of generation.

As a result of the loss of generation, the SH–PM line flow reduced to below its rating.

The loss of generation resulted in a low frequency in Tasmania. The frequency fell below 48 hertz (Hz), resulting in operation of the UFLS scheme. Around 170 MW of load was shed as a result of the UFLS operation.

AEMO gave permission to restore all load at 0949 hrs, and TasNetworks confirmed all load had been restored by 1045 hrs.

Both SH–GT No. 1 and No. 2 lines were returned to service at 1050 hrs.

Refer to Appendix A for a detailed sequence of events, and Appendix B for a diagram of the relevant part of the Tasmania transmission system.

# 4. ANALYSIS

## 4.1 TasNetworks investigation

This section is based on information provided by TasNetworks.

The simultaneous loss of both SH-GT transmission lines occurred while TasNetworks was commissioning a new radio link. As part of this telecommunications work, a part of the communications network was inadvertently left in a test mode that resulted in incorrect current values being fed into all three phases of the ‘B’ protection relays on the SH-GT1 and SH-GT2 lines. This caused operation of the differential protection, and, as the event was seen as a multi-phase fault, auto-reclose was not attempted.

As a result of the SH–GT1 and SH–GT2 line trips, the flow on the SH–PM 220 kV transmission line increased from approximately 123 MW to approximately 590 MW, representing about a 50% overload.

At 0939 hrs, restoration of the SH–GT2 line was attempted, by closing the circuit breaker for the SH–GT2 line at Sheffield. This caused a flow of charging current out of the Sheffield substation. It was of sufficient magnitude for the backup NCSPS to become active, since it now recognised the SH–GT disconnection as a single circuit loss, that is, a credible contingency event.

Once the backup NCSPS became active, it correctly took action to disconnect generation to reduce the flow on the SH–PM line.

Both SH–GT1 and SH-GT2 lines were returned to service at 1050 hrs.

TasNetworks has completed the following actions to reduce the probability of this type of event happening again:

- Changed the relay addressing of protection relays on the SH–GT lines, to prevent these from corrupting current measurements in case part of the communication network is left inadvertently in a test mode.
- Revised telecommunications commissioning and operating procedures to include a check for any loopback tests prior to transferring any protection devices across to a different bearer.
- A review of the reasonability limits used to determine data quality associated with the line flow values on the SH–PM line identified that the limits were set too low. This resulted in the line flow values sent to AEMO being tagged as bad quality. This is discussed further in section 5.1.1. Changes have been made to reasonability limits for all MW and megavolt amp (MVA) values on the SH-GT lines and a review of remaining lines initiated, to set them to twice the rating of the transmission line where practical.
- While the back-up NCSPS operated as designed, a review of the scheme's operating logic was conducted to identify any transmission lines in Tasmania covered by the back-up NCSPS that were exposed to potential overloading following a non-credible contingency. As a result of this review, changes to the logic associated with the SH-GT lines are proposed to ensure the scheme will protect the SH-PM line against the non-credible loss of both SH-GT lines. TasNetworks has advised AEMO that these changes will be made by 30 September 2017.

TasNetworks will also conduct an audit of protection schemes across the transmission system in Tasmania. TasNetworks has advised AEMO this will be completed by the end of April 2017.

## 4.2 Frequency

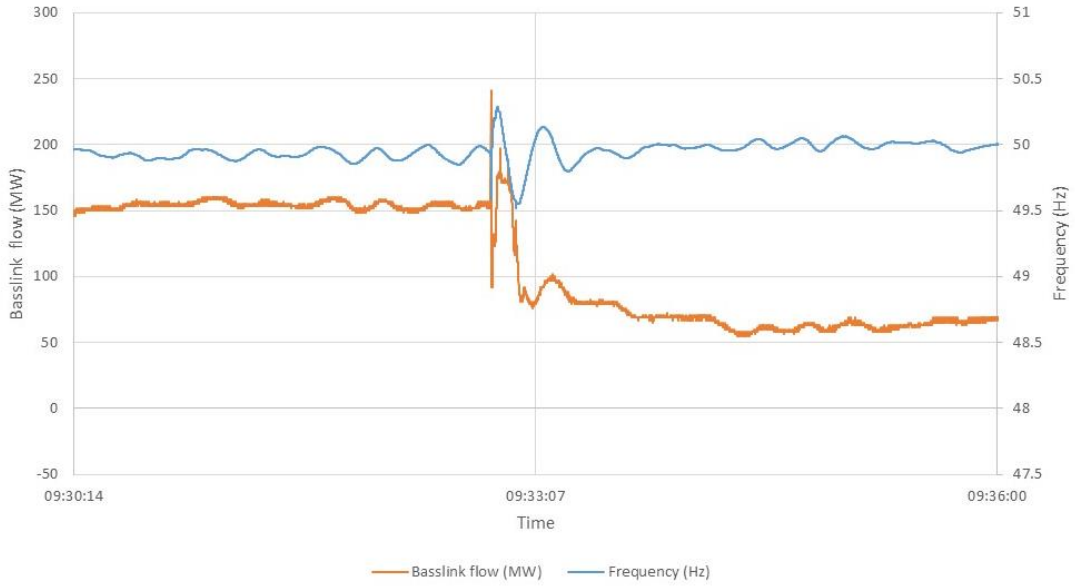
### 4.2.1 Trip of both Sheffield – George Town lines

Immediately after the trip of the SH–GT lines, the increased loading on the SH–PM line resulted in approximately 45 MW of additional losses on the transmission network, causing the frequency in Tasmania to fall to 49.74 Hz.

The Basslink frequency controller responded as designed, and reduced transfer from Tasmania to Victoria to restore the frequency to normal. Figure 2 shows the frequency in Tasmania and Basslink flow immediately after the loss of the lines.

For a network event, the frequency operating standard requires the frequency to remain within 48 to 52 Hz. The frequency standard was met.

**Figure 2 Tasmania frequency and Basslink flow immediately after loss of SH–GT lines**




### 4.2.2 Loss of Mersey Forth generation

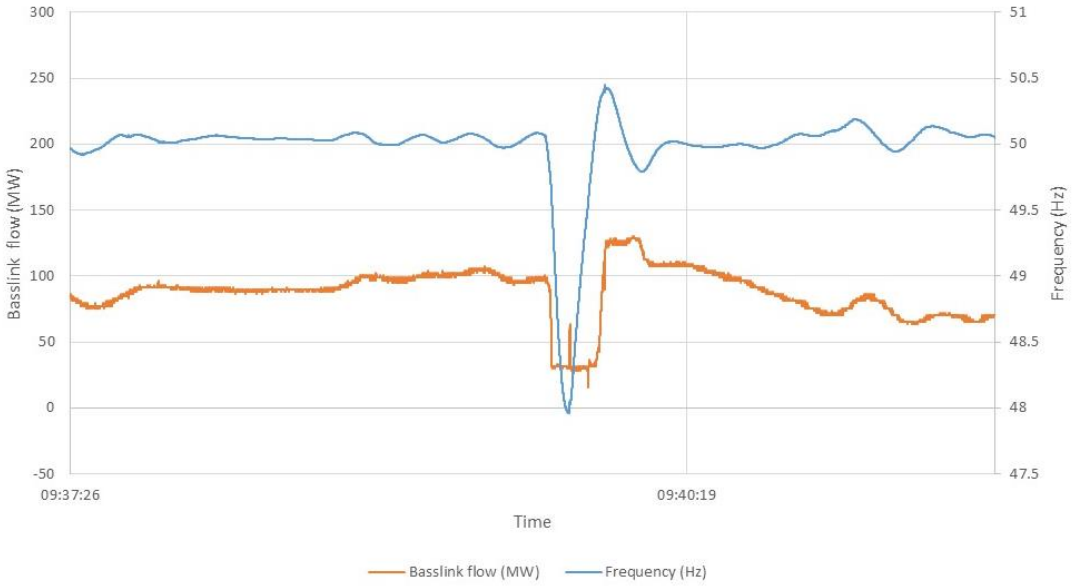
After the operation of the backup NCSPS and the disconnection of 217 MW of generation in the Mersey Forth area, the frequency in Tasmania fell to 47.96 Hz, as shown in Figure 3. This resulted in operation of the UFLS scheme. Around 170 MW of load was shed as a result of the UFLS operation.

The UFLS operated as expected.

For a multiple contingency event, the frequency standard requires the frequency to remain above 47 Hz, return to above 48 Hz within two minutes, and return to above 49.85 Hz within 10 minutes.

The frequency standard was met for this event.

**Figure 3 Tasmania frequency and Basslink flow after loss of the Mersey Forth generation**



### 4.2.3 Basslink response

In response to the generation loss and subsequent low frequency in Tasmania, the Basslink frequency controller operated as designed and rapidly reduced the transfer from Tasmania to Victoria to assist in correcting the frequency, as shown in Figure 3.

Basslink flow reduced from approximately 100 MW to approximately 50 MW. The Basslink frequency controller is not able to reduce the flow to below approximately 50 MW.

### 4.2.4 FCAS response

Table 1 shows the contingency raise FCAS enabled in Tasmania immediately prior to the generation trip (dispatch interval ending 0940 hrs).[8]

**Table 1 Contingency FCAS**

| Service | Enabled (MW) |
|---|---|
| Fast raise | 53 |
| Slow raise | 50 |
| Delayed raise | 96 |

Based on information provided by Hydro Tasmania, AEMO has analysed the performance of the fast raise FCAS that was enabled on generating units in Tasmania.

Table 2 shows the generating units that were enabled to provide fast raise FCAS, and the amount actually delivered. As the generating units at Cethana, Devils Gate and Fisher tripped as part of the event, they were not able to deliver the enabled FCAS.

The total amount of fast raise FCAS delivered by the generating units available to deliver was greater than the total amount enabled.

**Table 2: Fast raise FCAS performance**

| Generating unit | Enabled MW | Delivered MW |
|---|---|---|
| Cethana | 2 | N/A |
| Devils Gate | 0.43 | N/A |
| Fisher | 2 | N/A |
| Gordon | 38.49 | 55.7 |
| Trevallyn | 1.83 | 2.1 |
| Tribute | 5.08 | 7.5 |
| Tungatinah | 3.26 | 7.6 |
| Total | 53.09 | 72.9 |

As the Tasmania frequency recovered to within the normal frequency operating band within approximately seven seconds, there was no requirement for the generating units enabled for slow raise and delayed raise FCAS to deliver this service.

# 5. POWER SYSTEM SECURITY

AEMO is responsible for power system security in the National Electricity Market (NEM). This means AEMO is required to operate the power system in a secure operating state to the extent practicable and

[8] The preliminary report quoted values for the dispatch interval ending 0935 hrs. It is more appropriate to consider the dispatch interval 0940 hrs as these are the amounts enabled when the generation in Tasmania tripped.

take all reasonable actions to return the power system to a secure state following a contingency event in accordance with the NER.[9]

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

The flow on the SH–PM 220kV line was above its nominal rating for seven minutes. During this period the power system in Tasmania was not in a satisfactory operating state. AEMO gave permission to TasNetworks to restore the SH–GT lines at 0935 hrs. If either of these lines was returned to service, the flow on the SH–PM line would have been reduced to below its nominal rating, restoring the power system to a satisfactory operating state. The power system returned to a satisfactory operating state at 0939 hrs, after the generation in the Mersey Forth area was disconnected.

To manage power system security, AEMO invoked constraint set T-X_GTSH[10] at 0940 hrs to manage the outage of both SH–GT lines (see Section 5.1 below). No other action was required to maintain power system security.

## 5.1 Constraints

As noted above, AEMO invoked constraint set T-X_GTSH. This constraint set contains a number of constraint equations. From the dispatch interval ending 0945 hrs to the dispatch interval ending 0955 hrs, a number of these constraint equations were violating (as shown in Table 3). Violating constraints are an indication that the power system may not be in a secure operating state. Analysis after the event shows the power system was not in a secure operating state for up to 15 minutes. The constraints violated due to the time taken to change outputs of generating units to reduce the flow across the SH–PM line.

**Table 2 Constraint violation**

| | T>T_NIL_BL_IMP_5F[A] | T_X_GTSH_1[B] |
|---|---|---|
| **Violation DI 0945** | 1.48 MW | 263 MW |
| **Violation DI 0950** | Nil | 118 MW |
| **Violation DI 0955** | Nil | 56 MW |

A. Out = nil, avoid void O/L Hadspen to Georgetown No. 1 220 kV line (flow to North) for trip of the Hadspen to Georgetown No. 2 220 kV line.
B. Out = Both Georgetown to Sheffield 220kV lines, limit West Coast + Sheffield generation <= West Coast + North West load + 10MW, limiting SH–PM line flow to 10 MW.

### 5.1.1 Bad quality data

As noted in section 4.1, the line flow values for the SH–PM line sent to AEMO were tagged as bad quality, and as such would not be used by AEMO as inputs to constraint equations in the dispatch process. In these situations, AEMO will use the last good value received as the input to constraints.

For this event, the line flow values for the PM–SH line were tagged as bad quality for approximately 10 minutes, covering dispatch intervals ending 0940 hrs and 0945 hrs. During this period, the last good value for the SH–PM line flow (125 MVA) was used in constraints.

While this value was much less than the actual flow of approximately 600 MVA, this had no material impact on the dispatch process, because this value is only used in constraints to manage the flow on the SH–PM line to ensure neither of the SH–GT lines or the Palmerston – Hadspen (PM–HA) 220kV lines would be overloaded if the SH–PM line tripped. As both the SH–GT lines were out of service, the loss of the SH–PM line would have no impact on the flows on the SH–GT or PM–HA lines.

## 5.2 Reclassification

After any non-credible contingency event, AEMO is required to assess whether or not to reclassify the contingency as a credible contingency.

[9] Refer to AEMO's functions in section 49 of the National Electricity Law and the power system security principles in clause 4.2.6 of the NER
[10] Out = both Sheffield – George Town 220kv lines.

Based on advice from TasNetworks that the cause of the non-credible contingency had been identified, and that it was unlikely to reoccur, AEMO did not reclassify the loss of both SH–GT lines as a credible contingency event.

## 5.3 Outage advice

AEMO was not aware that TasNetworks was working on the communications system. In accordance with Section 9.2.3 of AEMO's Outage Assessment procedure[11], TasNetworks was not required to inform AEMO as this type of work generally poses no increased risk to the power system.

AEMO has considered whether a change to this procedure is required. Despite this particular occurrence, this type of work has historically posed no additional risk to the power system, and AEMO does not see any need to change the procedure. Even if AEMO had known of the work, AEMO would not have changed how the power system was operated. Any change to the procedure would simply add an administrative burden to TNSPs and AEMO.

Already, under the NER[12], if any System Operators like TasNetworks anticipate any work they do poses an increased risk to power system security, they are required to inform AEMO.

# 6. 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[13] over the course of this incident.

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

- Prompt advice of the occurrence of a major power system contingency.[14]
  - AEMO issued Market Notice 56344 at 0944 hrs (12 minutes after the event) to advise participants of the trip of both SH–GT Town lines (a non-credible contingency) in Tasmania.
  - AEMO issued Market Notice 56357 at 1022 hrs to advise participants of the trip of generation (a further non-credible contingency) and subsequent load reduction in Tasmania.
- Constraints invoked that impact interconnector transfer limits.[15]
  - AEMO issued Market Notice 56358 at 1036 hrs to advise participants that constraint set T-X_GTSH had been invoked.
  - AEMO issued Market Notice 56360 at 1108 hrs to advise participants that constraint set T-X_GTSH had been revoked.
- Updates on non-credible contingencies.
  - AEMO issued Market Notice 56359 at 1105 hrs to advise that the cause of the non-credible contingencies had been identified.

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

[11] Refer to SO_OP 3718 Outage Assessment.
[12] See NER clause 4.3.3(e)
[13] AEMO generally informs the market about operating incidents as they progress by issuing Market Notices.
[14] NER clause 4.8.3 and section 23 of the Power System Security Guidelines (SO_OP 3715).
[15] For short-term outages, AEMO is required to notify the Market of variances to interconnector transfer limits. AEMO, *Power System Security Guidelines,* Section 22.

# 7. 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:

- The simultaneous trip of both SH–GT 220 kV lines was a non-credible contingency and occurred as the result of the incorrect operation of protection equipment during planned work on communications equipment.
- The power system was not in a satisfactory operating state for seven minutes.
- The power system was not in a secure operating state for 15 minutes.
- The UFLS, backup NCSPS, and Basslink frequency controller operated as designed.

# 8. PENDING ACTIONS

TasNetworks will conduct an audit of protection schemes across the transmission system in Tasmania. TasNetworks has advised AEMO this will be completed by 30 April 2017.

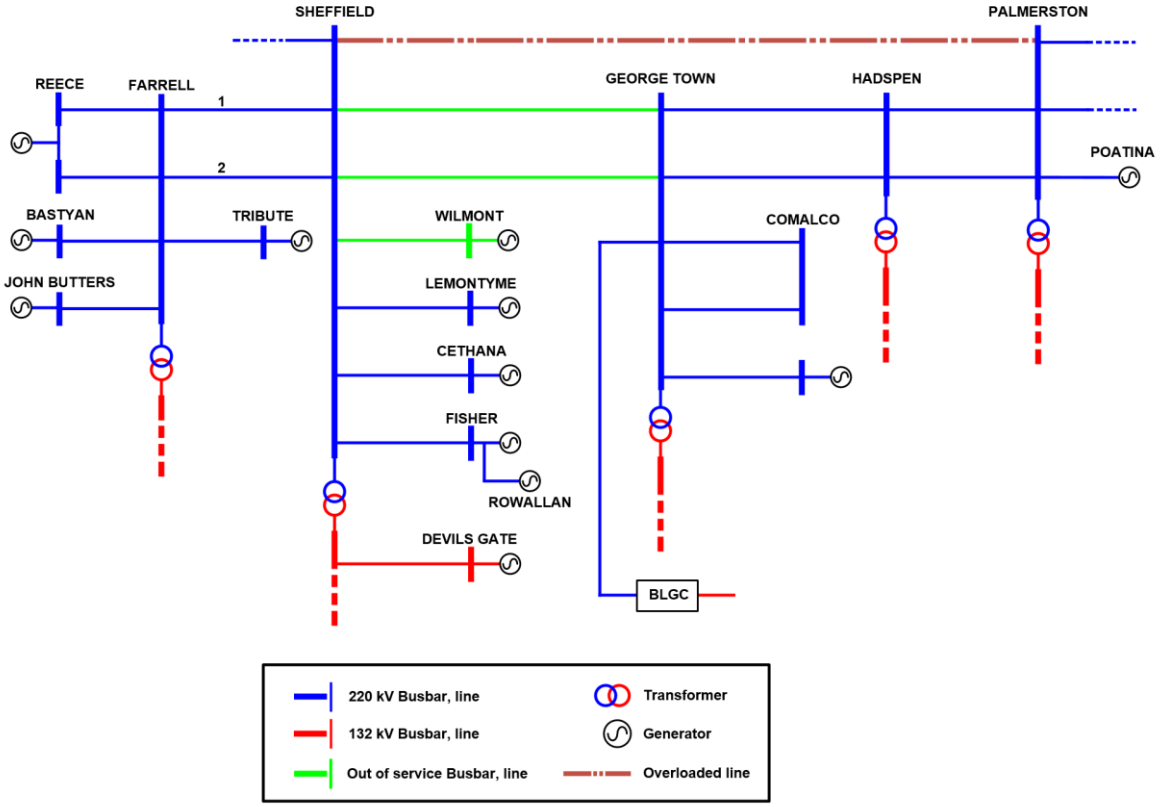
TasNetworks will revise the backup NCSPS logic associated with the SH–PM line by 30 September 2017.

# APPENDIX A. SEQUENCE OF EVENTS

| Time | Item |
|---|---|
| **0932 hrs** | SH–GT No. 1 and No. 2 220 kV transmission lines tripped simultaneously.<br>SH–PM 220 kV transmission line loaded to 150% of rating. |
| **0935 hrs** | AEMO gave permission to restore both SH-GT lines to service. |
| **0939 hrs** | TasNetworks attempted to restore SH–GT No. 2 line at Sheffield end.<br>Backup NCSPS operated and disconnected the Lemonthyme/Wilmot, Cethana, Fisher, and Devils Gate generating units.<br>SH–PM 220 kV transmission line flow below rating.<br>170 MW of customer load lost due operation of UFLS scheme. |
| **0940 hrs** | Constraint set T-X_GTSH invoked. |
| **0949 hrs** | AEMO gave permission to restore all load in Tasmania. |
| **1042 hrs** | TasNetworks advised AEMO that trip of the SH–GT lines resulted from work on communications systems. |
| **1042 hrs** | AEMO gave permission to restore both SH–GT lines. |
| **1045 hrs** | TasNetworks advise AEMO that load restored. |
| **1050 hrs** | Both SH–GT lines returned to service. |
| **1100 hrs** | Constraint set T-X_GTSH revoked. |

# APPENDIX B. SYSTEM DIAGRAM

**Figure 4 Transmission network in the Sheffield – George Town – Palmerston area of Tasmania**



# APPENDIX C. NCSPS AND BACK UP NCSPS

The network control system protection scheme (NCSPS) allows operation of specified transmission circuits in Tasmania to 95% of the line rating, on the basis that, if a contingency occurs resulting in a line overload, then suitable generating units will be either tripped or de-loaded to remove the line overload.

There is a primary and a backup NCSPS.

The primary NCSPS is only active when transmission line flows are high enough to cause an overload after a single credible contingency. On 20 December, as the primary NCSPS had not identified any potential line overload for the loss of either of the SH–GT 220 kV lines, the scheme was not armed to take action for the loss of these lines.

The backup NCSPS is permanently enabled, and is designed to operate if the primary NCSPS fails to operate correctly after a single credible contingency. On 20 December, the backup NCSPS initially did not operate, because the loss of the SH–GT 220kV lines was a non-credible contingency. However, when the SH–GT2 line was energised, the line energising current was interpreted by the backup NCSPS as the line being in service. As the SH–GT1 line was still out of service and the SH–PM 220 kV line was overloaded, the backup NCSPS interpreted this as a single credible contingency (loss of SH–GT1 line), and operated correctly to remove the overload on the SH–PM line.