UNDER FREQUENCY LOAD SHEDDING IN TASMANIA ON SUNDAY 2 AUGUST 2015

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

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

VERSION RELEASE HISTORY

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1	8 October 2015	Peter Biddle	Initial	Steve Darnell	James Lindley

INCIDENT CLASSIFICATIONS

Classification	Details
Time and date of incident	1043 hrs Sunday 2 August 2015
Region of incident	Tasmania
Affected regions	Tasmania
Event type	GL – Loss of generation and load interruption
Generation Impact	228 MW of generation was disconnected as a result of this incident
Customer Load Impact	225 MW of customer load was disconnected as a result of this incident
Associated reports	Operational Event Report – Trip of multiple transmission lines and resulting under frequency load shedding in Tasmania on Sunday 2 August. Published 4 August 2015.

ABBREVIATIONS

Abbreviation	Term
AEMO	Australian Energy Market Operator
UFLS	Under frequency load shed
kV	Kilovolt
MW	Megawatt
NER	National Electricity Rules
FCAS	Frequency Control Ancillary Services

IMPORTANT NOTICE

Purpose

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

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1. OVERVIEW

This report reviews a power system operating incident on Sunday 2 August 2015 in Tasmania. This incident involved the simultaneous trip of two transmission lines and subsequent loss of 228MW of generation. The loss of generation resulted in under-frequency load shedding of 225MW of customer load.

The power system is operated to remain in a satisfactory[1] operating state for the loss of single elements in the transmission network. Such events are defined as credible contingency[2] events. AEMO considers the occurrence of these events to be reasonably possible and ensures contingency plans are in place to minimise impact on the power system following a credible contingency event. A non-credible contingency event is anything other than a credible contingency event. On occasions AEMO may reclassify a non-credible contingency as a credible contingency[3].

AEMO is required to review this incident as it resulted in under-frequency load shedding. Specifically, 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. [4]

AEMO concluded that:

1. AEMO correctly reclassified the loss of both lines as a credible contingency before the incident.
2. The two transmission lines tripped due lightning.
3. The Frequency Standard in Tasmania was breached.
4. Constraints that AEMO had invoked prior to the incident were incorrectly formulated. The constraints have since been rectified.
5. The incorrectly formulated constraints resulted in insufficient frequency control ancillary service (FCAS) being enabled to cater for the trip of the transmission lines and subsequent loss of generation.
6. The power system was not in a secure operating state before this incident.[5]

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

2. THE INCIDENT

On Sunday 2 August 2015, a lightning storm was near the Farrell-Reece transmission lines. At 1029 hrs, AEMO, in accordance with operating procedures[8], reclassified the simultaneous trip of the Farrell-Reece (FA-RC) No.1 and No.2 220 kV transmission lines as a credible contingency. Constraint set F-T-FARE_N-2[9] was invoked at 1030hrs.

[1] Refer to NER 4.2.2
[2] Refer to NER 4.2.3
[3] Refer to NER 4.2.3A
[4] NER Clause 4.8.15 (b)
[5] AEMO is required to operate the power system in a secure state which means that the power system will return to a satisfactory state following a credible contingency event. See NER 4.2.2 and 4.2.4
[6] TasNetworks is the Transmission Network Service Provider in Tasmania region.
[7] HydroTas is the operator of majority power stations in Tasmania region.
[8] SO_OP3715 – Power System Security Guidelines
[9] Sets FCAS requirements for when trip of both FA-RC lines declared as a credible contingency.

At 1043 hrs both FA-RC transmission lines tripped as a result of a lightning strike. The FA-RC No.1 line tripped and auto-reclosed at the Farrell end, and the FA-RC No.2 line tripped and remained out of service. As a result the two generating units at Reece Power Station were disconnected with the loss of 228 MW of generation.

The 228MW generation loss caused the Tasmanian power system frequency to fall to just under 48.0Hz, resulting in automatic under-frequency load shedding (UFLS) of about 225MW of customer load. Table 1 provides details of load lost.[10]

Table 1 Load Disconnection Summary

Load	MW
Bell Bay Aluminium	101 MW
Nyrstar	124 MW

The FA-RC No 1 and No.2 lines and Reece Power Station generating units were restored to service within 12 minutes of the incident. AEMO gave permission to restore all load at 1104 Hrs. All load was restored by 1143 Hrs.

Appendix A provides a chronology of events.

The reasons for investigating this incident are:

1. Tasmanian power system frequency breached the Frequency Operating Standard (of 48.0 Hz) for a network event. The frequency fell to a low of 47.951 Hz.
2. Under-frequency load shedding was initiated:
    - Automatic load shedding was triggered at 47.96 Hz.

The following sections outline the findings of the investigation.

3. TASNETWORKS INVESTIGATION

TasNetworks investigated this incident and found:

- The trip of both the FA-RC lines was caused by lightning.
- FA-RC1 line tripped on white phase to earth fault. Protection detected the fault, and tripped the FA-RC1 line. The fault was cleared within the mandated clearance time[11] and the line was automatically reclosed at the Farrell end. Although this was only a single phase trip and reclose, generating unit circuit breakers will trip and remain open in accordance with standard practice. The Reece 1 generating unit remained out of service.
- FA-RC2 line tripped on multi-phase to earth fault. Protection detected the fault, and tripped the FA-RC2 line. The fault was cleared within the mandated clearance time. The auto-reclose functionality does not operate for multiple phase faults. At 1052 hrs, nine minutes after the

[10] In the Operational Event Report published by AEMO on 4 August it was reported that 26MW of load was also shed at Norske Skog. This has subsequently been proven incorrect. While the load did trip a short time after the incident it was not initiated by the under frequency load shed system.

[11] NER Schedule 5.1a System Standards Clause S5.1a.8

incident, TasNetworks restored the FA-RC 2 line to service at the Farrell end. The Reece 2 generating unit remained out of service.

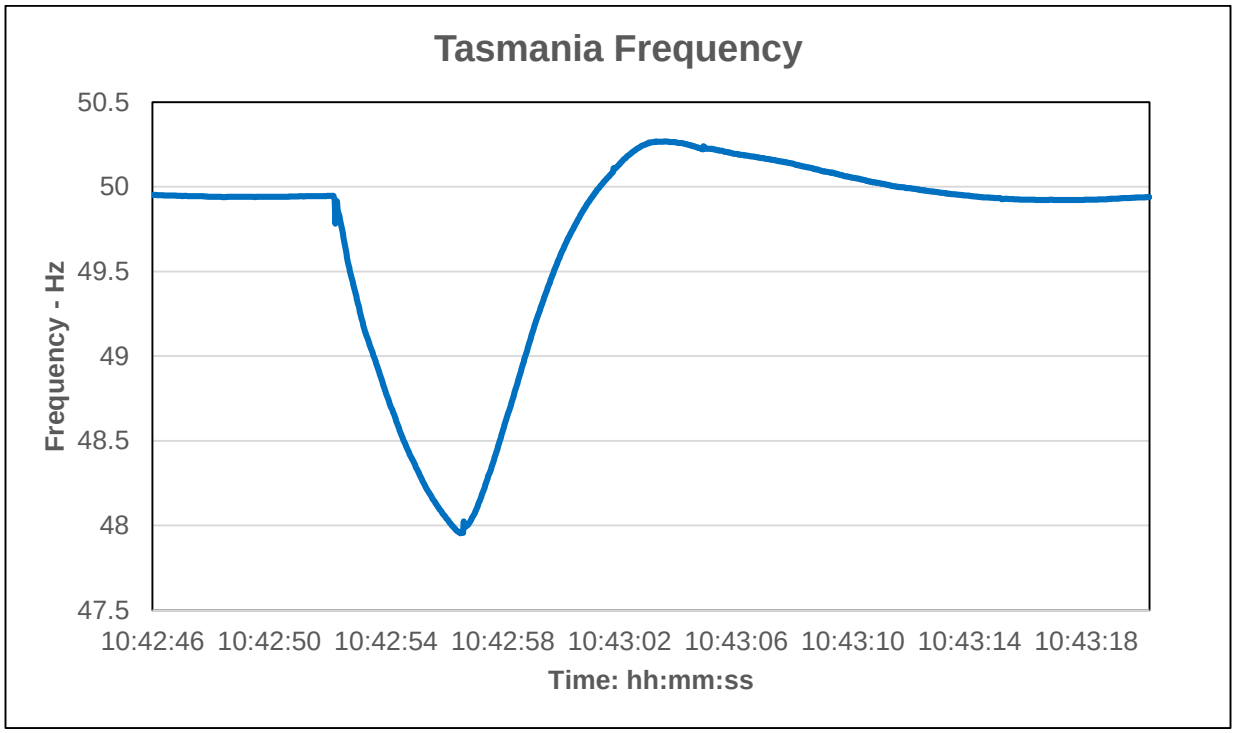
4. AEMO INVESTIGATION

4.1 Frequency

For a network event, the Frequency Standard for the Tasmania region requires the frequency to be contained to a minimum of 48.0Hz and return to the normal frequency band (49.85Hz) within 10 minutes. The frequency standard was not met for this incident.

For this incident, the minimum recorded frequency in the Tasmania region was 47.951Hz at 10:42:56hrs. The frequency returned to the normal operating band within eight seconds largely as a result of under frequency load shedding. Frequency in the mainland part of the NEM remained within the normal operating band. Figure 1 shows the frequency response for the Tasmania region.

Figure 1: Tasmania Frequency



Frequency response is governed in part by the amount of FCAS enabled and delivered. AEMO invoked FCAS constraint set F-T-FARE_N-2 for this incident. The purpose of this constraint set is to enable enough contingency FCAS to cover the loss of both FA-RC lines and consequently the loss of both Reece generating units.

To ensure frequency is contained above 48.0Hz, enough Raise six second (R6) FCAS must be provided. For the dispatch interval ending 1045hrs, constraint equation F_T++FARE_N-2_TG_R6[12] was

[12] Out=Nil, loss of both Farrell to Reece lines declared credible, Tasmania R6 requirement, Basslink able to transfer FCAS. (Part of constraint set F-T-FARE_N-2)

binding and determined that 122MW of R6 FCAS was required. Reece generation at the time was 228MW.

Of the 122MW of R6 required, 50MW was enabled on Tasmania's generating units and the remaining 72MW was obtained from the mainland via Basslink. This is on the basis that Basslink would respond, under its frequency control action, by at least 72MW in the event of a contingency. This change in Basslink flow enables the transfer of FCAS from the mainland for a contingency in Tasmania.

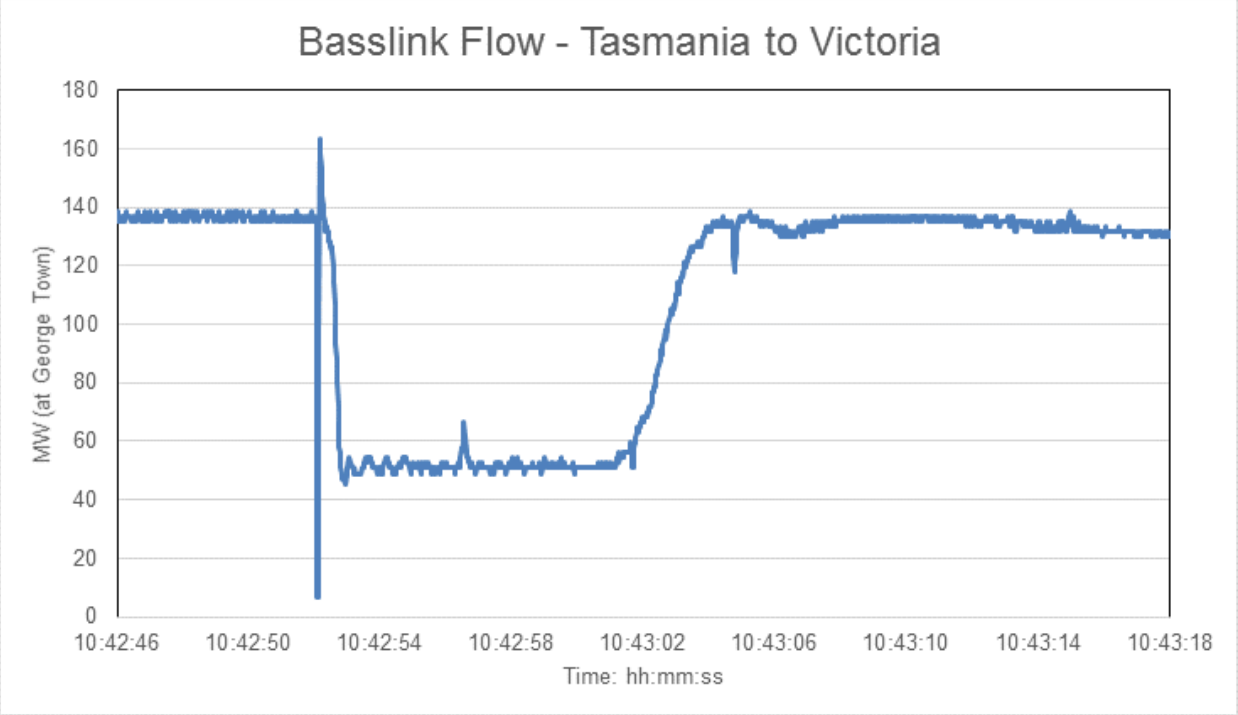
4.2 FCAS response

This section analyses the R6 FCAS response of Basslink and generating units in Tasmania.

4.2.1 Basslink

Figure 2 shows the response of Basslink to the incident. Before the incident, Basslink flow was about 135MW from Tasmania to Victoria. In response to the incident, Basslink flow reduced, under the action of its frequency controller, to 50MW, a change of about 85MW. This outcome is expected and consistent with the 72MW of R6 FCAS response expected from the mainland.

Figure 2. Basslink response



4.2.2 Tasmanian generating units

Hydro Tasmania provided high speed data to allow analysis of the R6 FCAS response on enabled generating units. AEMO has analysed the response of R6 enabled generating units in Tasmania in accordance with the Market Ancillary Service Specification using the FCAS Verification Tool[13]. The results

[13] Available on the AEMO website at http://www.aemo.com.au/Electricity/Market-Operations/Ancillary-Services/Specifications-and-Standards/Market-Ancillary-Service-Specification

are shown in Table 2. While delivery of R6 FCAS from some units was slightly below requirements, the total R6 FCAS delivered by enabled units was in excess of that enabled.

Table 2 – R6 FCAS response from enabled generating units

Unit	Enabled (MW)	Delivered (MW)	Comments
Gordon 1 and 2	31.3	49.5	Response is adequate
John Butters	12.9	21.0	Response is adequate
Liapootah 1, 2 and 3, Wayatinah and Catagunya	4.5	24.9	Response is adequate
Trevallyn	0.5	0.4	Response is adequate
Tribute	0.8	0.0	No response identified
Total	50	95.8	About 46 MW over delivery.

AEMO also considered the R6 response from generating units not enabled and therefore not required to provide the service. The results are shown in Table 3. While the response varies between power stations, the total response was negligible.

Table 3 - R6 FCAS response from generating units not enabled

Unit	Delivered (MW)	Comments
Devils Gate	-0.5	
Fisher	2.3	
Wilmot and Lemonthyme	0.3	
Poatina 220	3.2	
Tarraleah units 1, 2 and 3	-0.9	
Poatina 110	-	High speed data is unavailable
Tungatinah 3	-	High speed data is unavailable
Total	4.4	

4.3 FCAS Constraint formulation

This section reviews the operation of the constraints invoked in response to the reclassification.

AEMO invoked constraint set F-T-FARE_N-2 in response to reclassification of the FA-RC lines as a credible contingency. This constraint set contains a number of constraint equations to ensure sufficient FCAS is sourced to cover the contingency. AEMO has identified an error in formulating these constraint equations that results in insufficient FCAS being enabled. The error relates to the way the Basslink frequency controller response is treated.

As a result of this issue there was a deficiency of about 70MW in the amount of R6 FCAS enabled for the loss of both FA-RC lines.

Most system normal and outage FCAS constraints associated with Tasmania were affected by the formulation error. The error was introduced in July 2014. AEMO has reviewed and updated all FCAS constraints for Tasmania.

4.4 Rate of change of frequency

While there was a deficiency in the amount of R6 FCAS enabled, the over delivery of enabled R6 FCAS in Tasmania effectively reduced the deficit to only 25MW.

It is not clear if delivery of additional R6 FCAS from generating units in Tasmania would have prevented load shedding, as the rate of change of frequency may be faster than what could be corrected by R6 FCAS.

As noted in Section 4.1 the fall in frequency was largely arrested by operation of the UFLS scheme. Normally it is expected that R6 FCAS will limit the fall in frequency to ensure load shedding does not occur. While the lack of enabled R6 FCAS is a contributing factor to load shedding in this instance, AEMO is concerned that the existing processes for determining the FCAS requirements may not be appropriate when the rate of change of frequency is high. High rates of change of frequency can occur when power system inertia is low or the size of the contingency is large in relation to the size of the network. A high rate of change of frequency may reduce the capability of the R6 FCAS available in Tasmania to control frequency deviations to within the Frequency Standard. AEMO intends to further analyse this issue.

4.5 Performance of generating units

This section provides information on the fault ride through response of generating units in Tasmania.

Generator Performance Standards[14] require generating units to ride through or remain on line during most power system faults or frequency deviations.

During this incident all in-service generating units, apart from the Musselroe and Bluff Point wind farms, either increased or did not decrease outputs in response to the falling system frequency. This response is in accordance with the registered Generator Performance Standards. The response of the two wind farms during the incident is summarised below:

- At Musselroe Wind Farm two turbines tripped in response to the fault. This reduced the output from the wind farm by about 6 MW until the turbines were returned to service four minutes after the incident. AEMO is continuing to work with Hydro Tasmania to resolve this issue.
- At Bluff Point Wind Farm six turbines 'stopped' in response to the fault. In the stopped mode these turbines are still connected to the power system but provided no output. This resulted in reduced output of about 10 MW until the turbines were returned to service 12 minutes after the incident. AEMO is continuing to work with Hydro Tasmania to resolve this issue.

TasNetworks also identified about 6 MW of embedded generation that tripped as a result of this incident. There is no requirement under the National Electricity Rules for these type of generating units to ride through a fault on the transmission network or a frequency disturbance.

Reduced output from the wind farms and tripping of embedded generation further increased the supply/demand imbalance in Tasmania after the incident. While not considered as the primary cause of the under frequency load shedding, analysis by TasNetworks indicates a high probability that UFLS would not have occurred if this additional generation loss had not occurred.

[14] Determined in accordance with Chapter S5 of the National electricity Rules.

5. POWER SYSTEM SECURITY

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

AEMO has determined that the power system was not in a secure operating state prior to this incident.

The NER requires AEMO to maintain the power system in a secure operating state. For the power system to be in a secure operating state it must remain in a satisfactory operating state after any credible contingency event[15].

As the power system frequency was outside the frequency standard immediately after this incident, the power system did not remain in a satisfactory operating state. The power system was returned to a satisfactory operating state after about eight seconds as the result of the operation of the UFLS scheme.

The power system was not in a secure operating state from the time the loss of both FA-RC lines was reclassified until the incident occured, a period of about 14 minutes. The power system was also not in a secure operating state from when the Reece generating units returned to pre-incident generation levels to when the reclassification of the FA-RC lines was cancelled, a period of about 25 minutes.

As noted in Section 4.3 most system normal and outage constraints were affected by the formulation error. As a result of this error the power system in Tasmania may not have been in a secure operating state at all times. AEMO will continue to review the operation of FCAS constraints after July 2014 to determine if there was any material impact on power system security. However AEMO has identified that there would have been a greater chance of the power system being insecure during times when the generation at risk was larger than normal. This typically occurs during reclassification events. Between July 2014 and August 2015 there were 46 reclassification events in Tasmania where the generation at risk may have been greater than normal. As such, the power system may not have been secure for periods ranging from 30 minutes to four hours during these reclassification events.

6. MARKET ADVICE

In relation to this incident, AEMO is required to advise the market on the following matters:

- Reclassification of any non-credible contingencies as soon as practicable.
- Occurrence of any non-credible event within two hours of the event.

AEMO issued three market notices in relation to this incident

1. At 1029 hrs, AEMO issued Market Notice 49458 to notify the market of the following:
    - AEMO observed lightning in the vicinity of the FA-RC1 and FA-RC2 lines.
    - AEMO considered the simultaneous tripping of these lines was likely and therefore reclassified the tripping of FA-RC1 and FA-RC2 lines as a credible contingency.
    - AEMO invoked constraint set F-T-FARE_N-2,
2. At 1131 hrs AEMO issued Market Notice 49460 to notify the market of a non-credible contingency event in the Tasmania region.

[15] NER 4.2.4 & 4.3.1

3. At 1135 hrs, AEMO issued Market Notice 49461 to notify the market of cancellation of the reclassification of a non-credible contingency event, as lightning was no longer observed in the vicinity of the FA-RC1 and FA-RC2 lines.

7. CONCLUSIONS

AEMO concluded that:

1. AEMO correctly reclassified the loss of the FA-RC1 and FA-RC2 lines as a credible contingency.
2. The FA-RC1 and FA-RC2 lines tripped due lightning.
3. The Frequency standard for the Tasmania region was breached resulting in load shedding in the Tasmania region.
4. FCAS constraints with an incorrect formulation were invoked resulting in insufficient contingency FCAS being enabled. The constraints have since been rectified.
5. Enabled FCAS was delivered to the required level.The power system was not in a secure operating state prior to the incident.
6. The required advice to the market was provided by AEMO in a timely manner.

8. PENDING ACTIONS

1. AEMO will further investigate the performance of Musselroe and Bluff Point Wind Farms in relation to their respective Generator Performance Standards. This will be done in accordance with the Generator Performance Standard Compliance process.
2. AEMO will further investigate the ability of FCAS in Tasmania to control the rate of change in frequency.

APPENDIX A. CHRONOLOGY OF EVENTS

Time and Date	Event	Generation Loss (MW)	Load Loss (MW)
1029 hrs 2 August 2015	AEMO reclassified the loss of both FA-RC lines as a credible contingency and issued Market Notice 49458.		
1030 hrs 2 August 2015	AEMO invoked Constraint Set F-T-FARE_N-2.		
1043 hrs 2 August 2015	FA-RC1 & 2 lines tripped. The FA-RC 1 line Successfully auto-reclosed at Farrell. The FA-RC line remained out of service.	115 MW (Reece unit 1) 113 MW (Reece unit 2)	
1043 hrs 2 August 2015	Bell Bay Aluminium reduced load.		101 MW
1043 hrs 2 August 2015	Nyrstar reduced load.		124 MW
1053 hrs 2 August 2015	TasNetworks returned FA-RC2 line to service.		
1054 hrs 2 August 2015	Hydro Tasmania synchronised Reece unit 1 and unit 2. Both units returned to pre-trip generation level by 1105 hrs		
1055 hrs 2 August 2015	AEMO issued Permission to Proceed for Nyrstar to restore load. Load restored at 1143 hrs.		
1101 hrs 2 August 2015	AEMO issued Permission to Proceed for Bell Bay Aluminium to restore load. Load restored at 1135 hrs.		
1130 hrs 2 August 2015	AEMO cancelled the reclassification of the FA-RC lines and revoked Constraint Set F-T-FARE_N-2.		
1131 hrs 2 August 2015	AEMO issued Market Notice 49460 to notify the market of the non-credible contingency event.		
1135 hrs 2 August 2015	AEMO issued Market Notice 49461 to notify the market of the cancellation of the reclassification of a non-credible contingency event.		