AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Trip of the Calliope River – Boyne Island 7145 132 kV line, Gladstone Power Station Unit 1, and No. 3 Potline at Boyne Island on 16 February 2018

March 2019

Reviewable Operating Incident Report under the National Electricity Rules

INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of incident	2111 hrs on 16 February 2018
Region of incident	Queensland
Affected regions	Queensland
Event type	Lightning and protection maloperation
Generation impact	240 MW generation lost
Customer load impact	414 MW of industrial customer load lost
Associated reports	Nil

ABBREVIATIONS

Abbreviation	Term
3 potline	No. 3 potline at the Boyne Island aluminium smelter
7145 line	Calliope River – Boyne Island 7145 132 kV transmission line
AEMO	Australian Energy Market Operator
BSL	Boyne Smelters Ltd
CB	Circuit Breaker
GIS	Gas insulated switchgear
kV	Kilovolt
GPS1	Gladstone Power Station Unit 1
Hz`	Hertz
ms	Millisecond
MW	Megawatt
NEM	National Electricity Market
NER	National Electricity Rules
pu	Per unit
RPM	Revolutions per minute
TNSP	Transmission Network Service Provider
UPS	Uninterruptable power supply

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 16 February 2018 in Central Queensland. This incident involved the near simultaneous trip of the Calliope River – Boyne Island 7145 132 kV transmission line (7145 line), the Gladstone No. 1 generating unit (GPS1) and the No. 3 potline (3 potline) at the Boyne Island aluminium smelter.

There was a loss of 240 megawatts (MW) of generation and 414 MW of industrial customer load.

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[2].

AEMO has concluded that:

1. This non-credible contingency was initiated by a fault on the 7145 line caused by lightning. All protection operated correctly to clear the fault.
2. The trip of the Gladstone Power Station generating unit GPS1 was caused by a faulty turbine speed measuring device. The turbine speed measuring devices have been repaired.
3. The outage of the No. 3 potline was caused by the unexpected operation of the earth fault protection on a number of rectiformers in response to the line fault. The remaining rectiformers then tripped on over-current protection. The earth fault protection has been modified to reduce the likelihood of a recurrence.
4. A number of auxiliary systems at Boyne Smelters Limited (BSL) unexpectedly shut down due to the voltage disturbance from the line fault. Modifications to large motor contactors are being considered by BSL to allow motors to ride through short duration voltage disturbances to reduce the likelihood of a recurrence.
5. The power system remained in a satisfactory operating state over the course of the incident. The power system was not in a secure operating state for two periods, one of nine minutes and one of five minutes, during the course of this incident. AEMO took the appropriate actions to restore the power system to a secure operating state.
6. Based on the information available at the time of the incident, AEMO correctly did not reclassify the simultaneous loss of the 7145 line, No. 3 potline, and GPS1 as a credible contingency after the incident had occurred. If additional information made available during this investigation had been available at the time of the incident, it would have been appropriate to reclassify the loss of the three elements as a credible contingency until the cause of the unexpected tripping of rectiformers at Boyne Island had been resolved. Given that when this additional information was received, modifications to protection settings at BSL had already been made, further reclassification was not required.
7. AEMO correctly reclassified the simultaneous trip of the 7145 line and GPS1 as a credible contingency.
8. There was a delay of approximately 12 weeks in advising the market of the cancellation of the reclassification of the 7145 line and GPS1 due to a failure of AEMOs processes. There was no market impact as a result of this delay as no constraints were involved. The provision of all other market information was appropriate.

This report is prepared in accordance with clause 4.8.15 of the National Electricity Rules (NER). It is based on information provided by Powerlink, BSL, NRG Gladstone Power Station, CS Energy, and AEMO.

[1] See 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] See NER clause 4.8.15(b).

Australian Eastern Standard time (AEST) is used in this report.

2. The incident

On Friday 16 February 2018 at 2111 hrs, the 7145 line, GPS1, and No. 3 potline tripped near simultaneously, resulting in the loss of 240 MW of generation from Gladstone Power Station and 414 MW of load from the Boyne Island smelter.

There was lightning in the vicinity of the 7145 line and Boyne Island at the time of the incident.

The 7145 line automatically reclosed at Calliope River substation approximately 10 seconds after tripping, and was manually reclosed[3] at Boyne Island substation at 2120 hrs on 16 February 2018.

At 2149 hrs on 16 February 2018, the 7145 line was taken out of service at the request of BSL to repair damaged switchgear bushings. All load was restored by 2220 hrs on 16 February 2018.

The 7145 line was returned to service at 1102 hrs on 18 February 2018.

The probability of multiple power elements tripping simultaneously is very low, so it is an unexpected event known in power system security terms as a non-credible contingency event[4].

3. Incident investigation

3.1 Calliope River – Boyne Island 7145 132 kV transmission line outage

The following is based on information provided by Powerlink as Transmission Network Service Provider (TNSP) of the area in question.

The 7145 line tripped due to a high voltage fault on the line at the same time as a severe lighting strike was recorded[5] in the same area as the predicted fault location[6]. The fault was cleared within approximately 75 ms. Approximately 10 seconds after the line tripped, the line automatically reclosed at the Calliope River end to re-energise the line.[7]

A line patrol was conducted, and flashed insulators were found at the predicted fault location. The damaged insulators have been replaced.

3.2 Gladstone Power Station Unit 1 trip

The following is based on information provided by NRG Gladstone and CS Energy, as the operators of Gladstone Power Station.

The GPS1 unit tripped approximately 10 seconds after the fault on the 7145 line. The unit tripped as a result of a false acceleration rate signal.

[3] Auto-reclose is not fitted to the Boyne Island end of the 7145 line.

[4] See NER clause 4.2.3.

[5] The lightning strike was timed at 21:11:08.377 hrs.

[6] As determined by the line fault location systems.

[7] Auto-reclose is only installed at the Calliope River end of the line.

The generating units at Gladstone rely on three turbine speed measuring devices. The control system looks at all three devices and uses the highest value from the three devices. At the time of the incident, one device was giving erratic values but had not been isolated. The second device was operating normally but had been isolated and so was not available to the unit. The third device was operating normally but was powered by the uninterruptable power supply (UPS) which was on bypass[8] at the time of the incident.

When the fault occurred on the 7145 line, this resulted in a voltage disturbance on the transmission network which caused a momentary loss of supply to the speed measuring device supplied by the bypassed UPS. The only speed measuring device left available to the control system was the erratic device. At the time this device was showing a value of 333 RPM[9], resulting in the trip of the generating unit.

NRG Gladstone has been unable to identify why the turbine speed measuring device that was operating normally was isolated rather than the faulty (erratic) device. The UPS was on bypass due to a fault that occurred on 31 January 2018, and was scheduled for repair during a unit overhaul commencing on 28 February 2018. CS Energy advised AEMO on 25 May 2018 that the faulty UPS and faulty speed sensors had been replaced. The turbine speed monitoring devices on the other generating units at Gladstone had also been checked for correct operation.

3.3 Loss of No. 3 potline at Boyne Island

The following is based on information provided by BSL as the operator of the Boyne Island aluminium smelter.

In response to the fault on the 7145 line, the lightning surge arrestors at the Boyne Island substation operated to conduct the surge current into the earth grid. This had a number of consequences.

1. Operation of earth fault protection.
   - Electromagnetic induction and/or differences in voltage potential rises between the 132 kV tower where the fault occurred, the No. 3 potline rectiformers, and the Boyne Island substation earth grid, caused the sensitive earth fault protection on three of the rectiformers supplying the No. 3 potline to operate and trip the rectiformers at 21:11:08.449 hrs. This was not an expected outcome. The remaining in service rectiformers then tripped on overcurrent protection, resulting in the shutdown of the No. 3 potline.
   - BSL has advised AEMO that changes have been made to the sensitive earth fault protection to reduce the likelihood of a recurrence.
2. Operation of under-voltage protection.
   - The combination of the fault on the 7145 line and subsequent operation of the surge arrestors at Boyne Island substation caused the 132 kV supply voltage to the Boyne Island substation to collapse to less than 99 kV (0.75 pu) until the fault cleared[10]. This voltage dip was reflected in the 11 kV system and caused the shut-down of a number of auxiliary systems, such as compressor cooling pumps and fume treatment fans, due to the operation of under-voltage protection. This was not an expected outcome.
   - BSL has advised AEMO that changes to large motor contactors are being considered to reduce the likelihood of a recurrence.
3. Damage to gas insulated switchgear (GIS).
   - Operation of the surge arrestors caused the earth potential at Boyne Island substation to rise, causing a current to flow into the GIS. A copper pipe used to supply SF_6 gas[11] to the 7145 line bushing assembly

[8] The batteries and battery charger were not available for service.

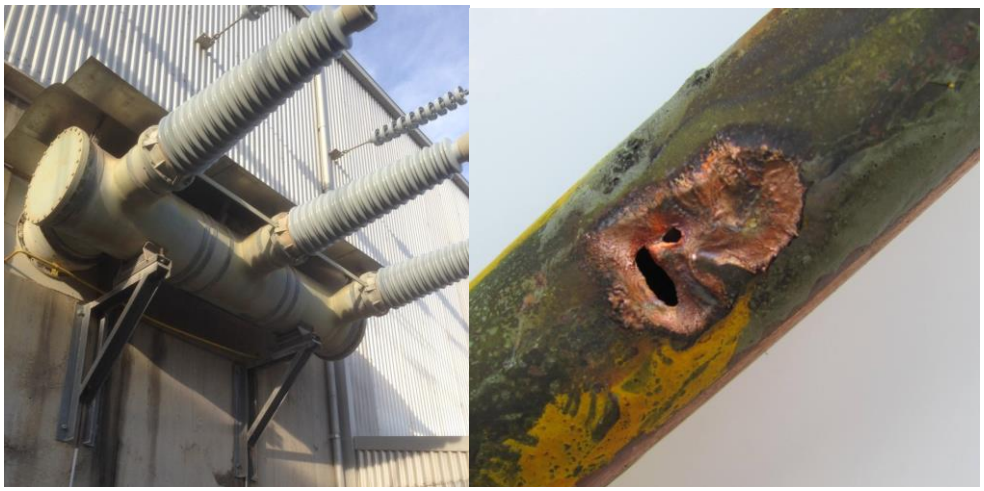
[9] Normal turbine speed is 3,000 RPM.

[10] After approximately 75 ms.

[11] SF_6 gas is a commonly used insulating medium in high voltage switchgear.

became part of this current path. Arcing between a support clamp and the copper pipe caused the copper pipe to fail and release the SF_6 gas from 7145 line bushing assembly. Figure 1 shows the 7145 line bushing assembly with the yellow copper SF_6 pipe and the resulting damage to the pipe.

Figure 1 7145 line bushing



Pictures supplied by Boyne Smelters Limited.

The 7145 line was automatically reclosed at the Calliope River end 10 seconds after the fault, and manually reclosed at the Boyne Island end at 2120 hrs. At 2149 hrs on 16 February 2018, BSL requested the 7145 line be removed from service to allow repairs to the bushing assembly. The repairs were completed, and the 7145 line returned to service at 1102 hrs on 18 February 2018.

Load restoration to the No. 3 potline commenced at 2200 hrs on 16 February 2018 and was complete by 2220 hrs on 16 February 2018.

4. 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 take all reasonable actions to return the power system to a secure state following a contingency event in accordance with the NER[12].

Immediately after the incident at 2111 hrs on Friday 16 February 2018, the power system was in a satisfactory operating state but not a secure operating state due to potential overloading of the Calliope River – Boyne Island 7146 132 kV transmission line on the loss of either the Wurdong – Boyne Island 865 275 kV transmission line or the Boyne Island No. 1 275/132 kV transformer. The power system returned to a secure operating state at 2120 hrs on 16 February 2018 when the 7145 line was returned to service.

At 2149 hrs on Friday 16 February 2018, when the 7145 line was taken out of service, the power system was again in a satisfactory operating state but not a secure operating state. The power system was returned to a secure operating state at 2154 hrs on 16 February 2018 when switching was carried out at Boyne Island substation to reconfigure the power system. A further reconfiguration of the power system was done at

[12] 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.

2230 hrs on 16 February 2018, after all load had been restored at Boyne Island to ensure the power system remained in a secure operating state.

Although no constraint sets were required to be invoked due to this incident, the system normal constraint set Q-NIL_BI_INTACT[13] was revoked at 2200 hrs on 16 February 2018 following the re-configuration switching at Boyne Island substation as the limit it manages was not present following the re-configuration. The constraint set was invoked again at 1110 hrs on 18 February after the 7145 line was returned to service and the power system returned to the normal configuration.

The frequency in the interconnected mainland power system rose to a maximum of 50.18 hertz (Hz) during this incident. The frequency returned to within the normal frequency band[14] within five seconds. The frequency standard was met for this incident.

4.1 Reclassification

AEMO assessed whether or not to reclassify this incident as a credible contingency[15].

When the 7145 line was returned to service on 18 February 2018, AEMO considered whether to reclassify the loss of this line, GPS1, and No. 3 potline at Boyne Island as a credible contingency.

Powerlink had passed on to AEMO advice they had received from BSL that the events at Boyne Island were due to a lightning strike directly on their plant, indicating that a second lightning strike shortly after the lightning strike that caused the outage of the 7145 line was the cause trip of the BSL potline. No information was available from Gladstone Power Station or CS Energy in relation to the trip of GPS1.

Based on this advice from Powerlink in relation to the trip of the potline, AEMO determined that a further simultaneous trip of the three elements – the 7145 line, the No. 3 potline, and GPS1 – due to a single lightning strike was unlikely and reclassification of these three elements as a credible contingency was not required.

However, on the basis that no information was available on the cause of the trip of GPS1, AEMO was not satisfied that a further trip of the 7145 line would not result in GPS1 tripping again. AEMO reclassified the loss of the 7145 line and GPS1 as a credible contingency at 1101 hrs on 18 February 2018. On 25 May 2018, CS Energy advised AEMO the issues with GPS1 had been resolved. Due to a failure in AEMO's process, the reclassification was not cancelled until 14 August 2018. This delay had no impact on the market, as no constraints were invoked as part of the reclassification. AEMO has reviewed its process for managing reclassifications in response to this delay.

As a result of the investigation into this incident, it has been determined that although there were two lightning strikes close together in both time[16] and location, the trip of the No. 3 potline occurred at the same time as the fault on the 7145 line, and not in response to a second lightning strike. Based on the information provided to AEMO at the time of the incident, AEMO made the correct decision in relation to reclassification. If AEMO had this additional information available at the time of the incident, it would have been appropriate to reclassify the simultaneous trip of all three elements – the 7145 line, the No. 3 potline, and GPS1 – as a credible contingency. If AEMO had made this reclassification, it would have had no impact on the market, as no constraints would have been required to be invoked for this reclassification.

On the basis of this additional information, AEMO again considered whether a fault on the 7145 line would likely result in the simultaneous trip of the No. 3 potline, and if reclassification was necessary. Based on the advice from BSL that modifications to the earth fault protection had been made, AEMO considered that reclassification was not required.

[13] Out= Nil, Boyne Island substation line bushing limit on Calliope River to Boyne Island 132 kV lines.

[14] 49.85 Hz to 50.15 Hz.

[15] AEMO is required to assess whether or not to reclassify a non-credible contingency event as a credible contingency event – NER clause 4.2.3A(c), and to report how the reclassification criteria were applied – NER clause 4.8.15(ca).

[16] The second lightning strike was timed at 21:11:08.783 hrs, approximately 0.4 seconds after the lighting strike on the 7145 line.

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:

- The occurrence of a non-credible contingency event – notify within two hours of the event[18].
  - AEMO issued Market Notice 62895 at 2136 hrs – 25 minutes after the event
- Update on non-credible contingency events.
  - AEMO issued Market Notice 61368 at 1206 hrs on 18 February 2018 to advise that the cause of the non-credible contingency had been evaluated and AEMO would reclassify the loss of the 7145 line and GPS1 as a credible contingency event.
- Advice about reclassification.
  - AEMO issued Market Notice 61369 at 1207 hrs on 18 February 2018 to advise that the simultaneous loss of the 7145 line and GPS1 was a credible contingency.
  - AEMO issued Market Notice 63869 on 14 August 2018 to cancel the reclassification.

6. Conclusions

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. This non-credible contingency was initiated by a fault on the 7145 line caused by lightning. All protection operated correctly to clear the fault.
2. The trip of the Gladstone Power Station generating unit was caused by a faulty turbine speed measuring device. The turbine speed measuring devices have been repaired.
3. The outage of the No. 3 potline was caused by the unexpected operation of the earth fault protection on a number of rectiformers in response to the line fault. The remaining rectiformers then tripped on over-current protection. The earth fault protection has been modified to reduce the likelihood of a recurrence.
4. A number of auxiliary systems at BSL unexpectedly shut down due to the voltage disturbance from the line fault. Modifications to large motor contactors are being considered by BSL to allow motors to ride through short duration voltage disturbances to reduce the likelihood of a recurrence.
5. The power system remained in a satisfactory operating state over the course of the incident. The power system was not in a secure operating state for two periods, one of nine minutes and one of five minutes,

[17] AEMO generally informs the market about operating incidents as the progress by issuing Market Notices – see AEMO website at https://aemo.com.au/Market-Notices.

[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. Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715---Power-System-Security-Guidelines.pdf.

during the course of this incident. AEMO took the appropriate actions to restore the power system to a secure operating state.

6. Based on the information available at the time of the incident AEMO correctly did not reclassify the simultaneous loss of the 7145 line, No. 3 potline, and GPS1 as a credible contingency after the incident had occurred. If additional information made available during this investigation had been available at the time of the incident, it would have been appropriate to reclassify the loss of the three elements as a credible contingency until the cause of the unexpected tripping of rectiformers at Boyne Island had been resolved. Given that when this additional information was received, modifications to protection settings at BSL had already been made, further reclassification was not required.
7. AEMO correctly reclassified the simultaneous trip of the 7145 line and GPS1 as a credible contingency.
8. There was a delay of approximately 12 weeks in advising the market of the cancellation of the reclassification of the 7145 line and GPS1 due to a failure of AEMOs processes. There was no market impact as a result of this delay as no constraints were involved. The provision of all other market information was appropriate.