

POWER SYSTEM INCIDENT REPORT TRIPPING OF ROBERTSTOWN – PARA AND ROBERTSTOWN – TUNGKILLO LINES SIMULTANEOUSLY ON 11 FEBRUARY 2011

PREPARED BY: ESOPP
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FINAL

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1 Introduction

At 1159 hrs on 11 February 2011 the Robertstown – Tungkillo and the Robertstown – Para 275 kV lines in South Australia (SA) tripped simultaneously, resulting in the interruption of approximately 170 MW of SA load. This incident took place at a time of severe lightning activity in the area.

This report has been prepared in accordance with clause 4.8.15 of the National Electricity Rules (NER) 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.

ElectraNet and ETSA Utilities have provided information to AEMO for this investigation. Data from AEMO’s Energy Management System and Market Management System has also been used in investigating the incident.

All references to time in this report refer to the Market time (Australian Eastern Standard Time).

2 Summary of Events

On 11 February 2011, the Robertstown – Tungkillo and Robertstown – Para 275 kV lines simultaneously tripped. The sequence of relevant events in this tripping and the subsequent restoration of the power system are shown in Table 1.

Time	Event or Action
1159 hrs	<p>A high voltage transmission network fault resulted in the simultaneous trip of the Robertstown – Tungkillo and Robertstown – Para 275 kV lines. Lightning activity was present in the Riverland area of SA at the time.</p> <p>The trip of these lines resulted in the opening of the Robertstown circuit breakers 6571, 6572, 6574 and 6575, which offloaded the Robertstown T2 275/132 kV transformer as shown in Figure 1.</p> <p>The power system disturbance caused by the network fault, subsequent trip of the 275 kV lines and the offloading of the Robertstown T2 transformer resulted in approximately 170 MW of load loss in SA.</p> <p>Circuit breakers 4555 and 4552, which connect the Angaston generating units to the No. 1 and 2 Angaston 33 kV buses, also opened. These two units were not generating at the time.</p> <p>Immediately after the lines tripped the power system was in an insecure operating state.</p>
1200 hrs	Both 30 MVar 66 kV capacitor banks at ETSA Utilities’ Cheltenham distribution substation tripped.
1202 hrs	<p>AEMO’s realtime network analysis applications indicated a number of security violations. The most significant security violation was the potential for the post-contingent flow on the Waterloo East – Waterloo 132 kV line to exceed its rating by up to 45% on the loss of the Davenport – Bungama 275 kV line. The next most significant security violation was the potential for the Robertstown T1 275/132 kV transformer flow to exceed its rating on the loss of either the Davenport – Brinkworth or the Davenport – Bungama 275 kV lines.</p> <p>AEMO invoked outage constraint set S-RBPA+RBTU+RBTX to ensure the power system would operate in a secure operating state during the outage of the Robertstown – Para and Robertstown – Tungkillo 275 kV lines and the Robertstown T2 275/132 kV transformer.</p> <p>AEMO subsequently assessed that these two security violations were progressively reducing in magnitude and would be removed completely by approximately 1220 hrs.</p>
1213 hrs	AEMO issued Electricity Market Notice ¹ No. 34491 to notify participants of the occurrence of this non-credible contingency event in SA.
1220 hrs	After initially reducing, the degree of security violation began to increase again. AEMO then identified that constraint set S-RBPA+RBTU+RBTX did not contain a constraint equation to maintain power flow on the Waterloo East – Waterloo 132 kV line within its rating on the loss of the Davenport – Bungama 275 kV line. The constraint set contained other constraint equations that bound for other contingency events and initially assisted in reducing the security violations on the Waterloo East – Waterloo 132 kV

¹ This Electricity Market Notice has been issued in accordance with Clause 4.8.3 in the NER.

	<p>line.</p> <p>AEMO consequently used its constraint automation facility to build constraint set CA_BPS_3C672E99 for this contingency event, having determined that constraint set S-RBPA+RBTU+RBTX would not remove the security violation.</p>
1239 hrs	AEMO invoked constraint set CA_BPS_3C672E99. This set contained a constraint equation to prevent post-contingent overloading of the Waterloo East – Waterloo 132 kV line on the loss of the Davenport – Bungama 275 kV line.
1318 hrs	AEMO issued Electricity Market Notice No. 34492 to notify participants of the occurrence of this non-credible contingency event in SA and other relevant information available at the time.
1336 hrs	ElectraNet reconfigured the network to prevent overloading of the Robertstown T1 275/132 kV transformer, as shown in Figure 2. The Robertstown – Para 275 kV line was isolated at the Robertstown end, and its 275 kV circuit breakers 6574 and 6575 were closed, which placed the Robertstown T2 275/132 kV transformer on load.
1344 hrs	AEMO blocked the binding constraint equation S>>V_RBTX_RBTX_MW4RB within the constraint set S-RBPA+RBTU+RBTX. This constraint equation is designed to prevent overloading of the Morgan Whyalla Pipeline Pump 4 – Robertstown 132 kV line during a prior outage of one of the Robertstown transformers on the loss of the remaining transformer, however, this constraint equation was no longer required as both Robertstown transformers were now in service. Figure 3 shows an overview of the SA network in the Robertstown-Waterloo area.
1348 hrs	AEMO revoked constraint set CA_BP_3C672E99 and replaced it by invoking new constraint set CA_BP_3C673EE1. AEMO built this constraint set using its constraint automation facility to account for the change in network topology due to placing the Robertstown T2 275/132 kV transformer on load.
1530 hrs	ElectraNet completed its line patrols and found no evidence of line damage. The Robertstown – Tungkillo 275 kV line was returned to service.
1533 hrs	The Robertstown – Para 275 kV line was returned to service.
1536 hrs	AEMO revoked constraint sets CA_BP_3C673EE1 and S-RBPA+RBTU+RBTX.

Table 1: Sequence of events following the tripping of Robertstown – Tungkillo and Robertstown – Para 275 kV lines and the subsequent actions to restore power system security

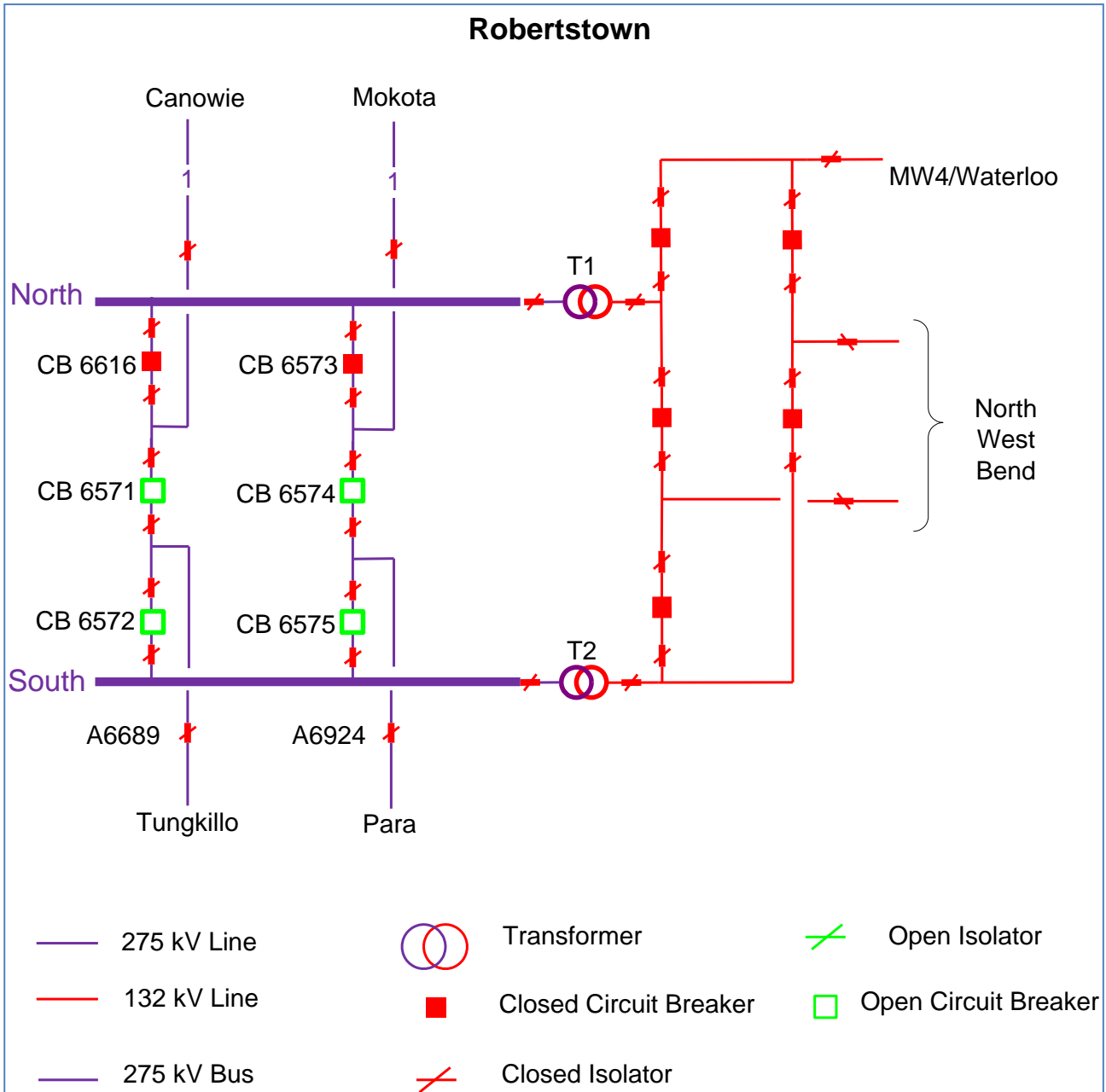


Figure 1: Robertstown 275 kV substation immediately after the trip of the Robertstown – Para and Robertstown – Tungkillo 275 kV lines

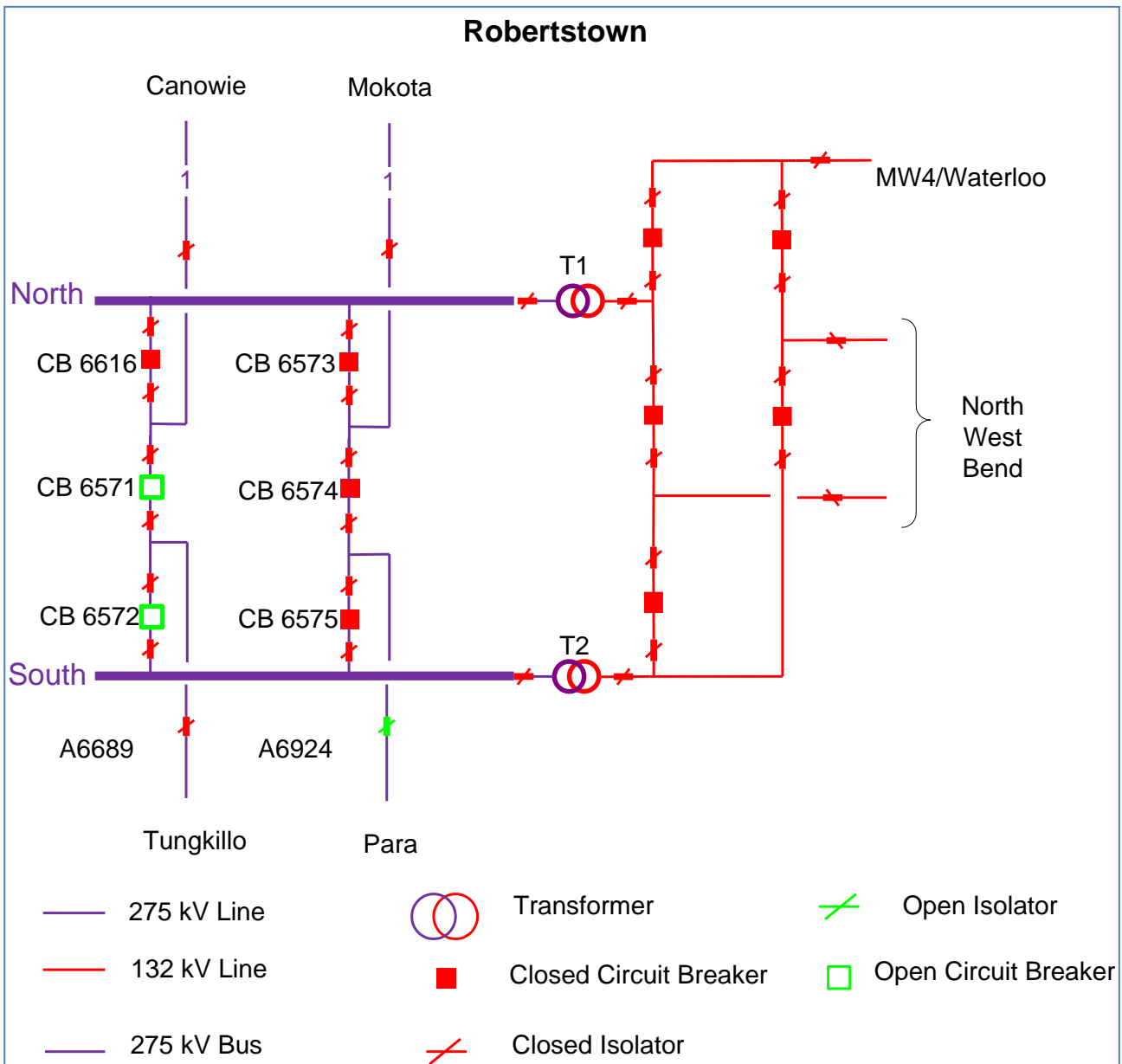


Figure 2: Robertstown 275 kV substation with the T2 275/132 kV transformer switched back into service

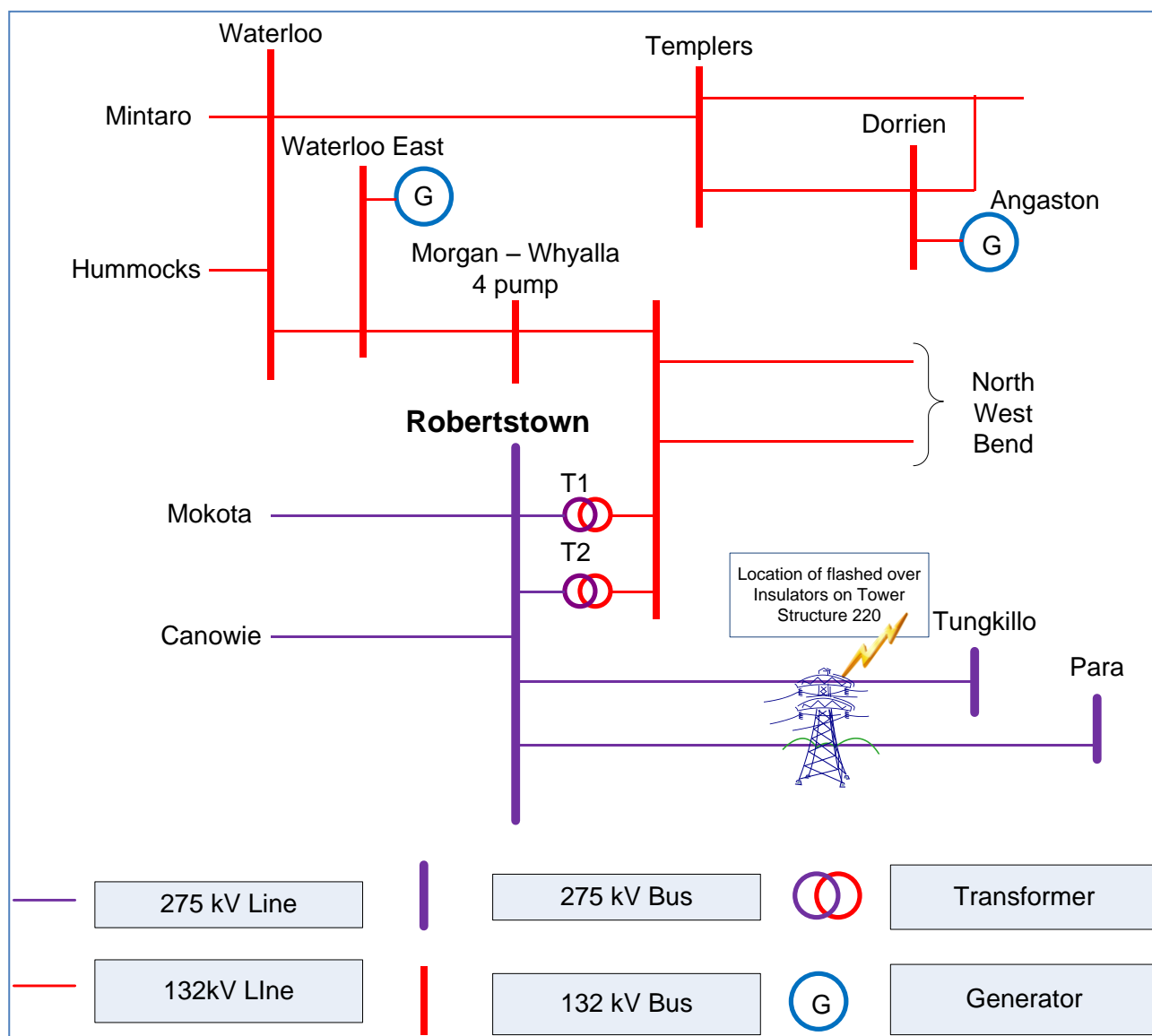


Figure 3: Overview of the South Australian network around the Robertstown-Waterloo area

3 Follow-up Actions

ElectraNet

On 16 February 2011, ElectraNet completed its post-fault aerial inspection of the Robertstown – Tungkillo and the Robertstown – Para 275 kV lines and reported flashed-over insulators on two phases on both lines at tower structure 220². ElectraNet has since replaced the flashed-over insulators.

On 10 March 2011, ElectraNet recorded tower footing resistance measurements for towers 218 to 222. The results verified that the footing resistances of these towers were satisfactory; as they were below 40 Ohms which is the upper limit specified in ElectraNet’s design manuals for 275 kV lines.

² The position of tower structure 220 has been deemed a prime location for back-flashover phenomena due to its position on top of a hill, having less natural coverage therefore with a higher probability of experiencing a lightning strike. The ground is also made up of rocky terrain which results in higher tower footing resistance during dry conditions.

On 15 March 2011, ElectraNet tested the replaced insulators at its Magill test facility to identify if there were any insulator defects causing this flash-over. The test results indicated that the performance of the insulators was satisfactory given their age.

ElectraNet is conducting further investigations into the coordination of transmission tower footing resistance and the performance of insulators.

ElectraNet will conduct a lightning performance study on their high voltage transmission lines. The study will investigate back-flashover rate versus tower footing resistance and shielding wire failure. The study will also determine if increasing insulator lengths is beneficial in reducing back-flashovers. ElectraNet will report the study's findings to AEMO by 31 July 2011.

AEMO

At the time of this incident the Robertstown – Tungkillo and Robertstown – Para double circuit transmission lines were not listed by AEMO as 'Vulnerable Transmission Lines' in its Power System Operating Procedure SO_OP3715 "Power System Security Guidelines"³. Hence, AEMO did not reclassify their trip as a credible contingency event on the occurrence of a cloud to ground lightning strike in the 'Lightning Attachment Zone' or 'Lightning Warning Zone' sections of that Procedure.

Later that day, AEMO updated Power System Operating Procedure SO_OP 3715 to include the Robertstown – Tungkillo and Robertstown – Para double circuit transmission lines in the list of 'Vulnerable Transmission Lines' with a category of 'Probable', and issued Electricity Market Notice No. 34493 advising of this update. This allows AEMO to reclassify the simultaneous trip of the Robertstown – Tungkillo and Robertstown – Para double circuit transmission lines as a credible contingency event on the occurrence of cloud to ground lightning strikes in the vicinity of the line.

On 15 February 2011 AEMO updated constraint set S-RBPA+RBTU+RBTX to include constraint equations to:

- Maintain power flow on the Waterloo East – Waterloo 132 kV line within its rating on the loss of the Davenport – Bungama 275 kV line.
- Maintain power flow on the Robertstown T1 275/132 kV transformer within its rating on the loss of either the Davenport – Bungama or Davenport – Brinkworth 275 kV lines.

On 22 February 2011 AEMO issued Electricity Market Notice No. 34607 to notify participants that:

- lightning was the cause of this incident; and
- if AEMO reclassifies a simultaneous trip of the Para – Robertstown and Robertstown – Tungkillo 275 kV lines as a credible contingency event due to lightning, AEMO will also include the trip of Angaston generating units No.1 and 2 as part of that credible contingency event until AEMO receives advice that those units are no longer likely to trip under those circumstances.

ETSA Utilities

ETSA Utilities has requested Infratil Energy Australia Pty Ltd (IEA) to advise if they require any changes to the existing protection relay settings on the two 33kV circuit breakers 4552 and 4555 at Angaston substation.

ElectraNet has commenced studies to assess the impact of this type of network fault on the Angaston generating unit "rate of change in system frequency" protection if the Angaston units were generating. ETSA Utilities, IEA and ElectraNet are investigating the design of the protection scheme to ensure correct operation and avoid inadvertent tripping of the Angaston units.

³ AEMO Operating Procedure SO_OP 3715 Power System Security Guidelines is available at the following web page for further details: <http://www.aemo.com.au/electricityops/3715.html>

4 Power System Security Assessment

Both the Robertstown – Para and Robertstown – Tungkillo 275 kV lines are strung on double circuit⁴ towers between Robertstown and Tungkillo 275 kV substations. The Robertstown – Para 275 kV line has a fly-over design at Tungkillo 275 kV substation before continuing to Para 275 kV substation.

A lightning strike in the vicinity of the double circuit tower line approximately 100 km from Robertstown is believed to have caused the transmission network fault. The lightning strike resulted in simultaneous faults on both the Robertstown – Para and Robertstown – Tungkillo 275 kV lines. The two transmission lines tripped within 2 ms of each other, and the time of tripping and the fault location correlates with the time the lightning strike was observed by ElectraNet’s lightning detection system.

The fault on the Robertstown – Para 275 kV line was cleared in 74 ms and the fault on the Robertstown – Tungkillo 275 kV line was cleared in 76 ms, with correct operation of the relevant protection equipment and circuit breakers. Both faults were cleared in accordance with the requirements specified in the NER⁵. There was no auto-reclose attempt on either line because the faults detected involved two phases to ground. ElectraNet patrolled the lines and returned them to service within 3.5 hours.

Approximately 170 MW load loss was observed in SA due to this incident and AEMO issued the Electricity Market Notice⁶ Nos. 34491 and 34492. Power system frequency remained within the normal operating frequency band throughout the incident.

The load loss was distributed across SA, with a higher proportion occurring close to the location of the transmission line fault, but there is no record of load interruptions initiated from protection or control action. The maximum percentage of load lost was recorded in the Riverland area (18%) and about 1% load lost in the South East area, for an average 9% load lost across SA. The load loss has been attributed to the voltage depression experienced during the network fault. Figure 4 shows the SA regional load change during this incident and the gradual load recovery within approximately 20 to 25 minutes.

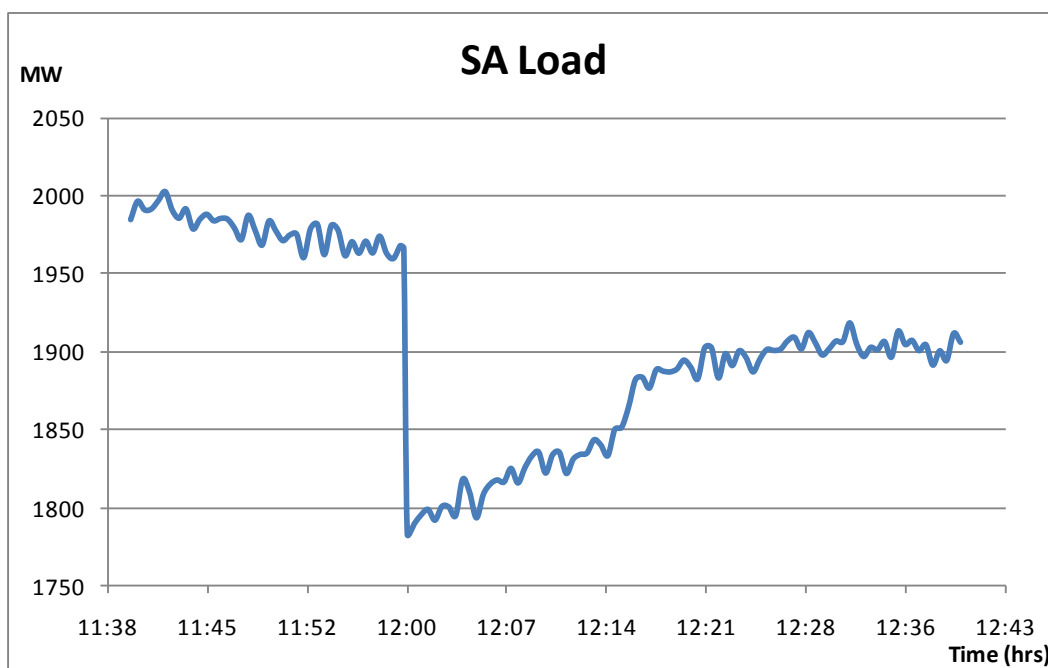


Figure 4: South Australian Regional Load between 1140 hrs and 1240 hrs

⁴ Double circuit transmission lines are parallel transmission lines that share common transmission towers.

⁵ Refer Schedule S5.1a.8 in the NER.

⁶ This Electricity Market Notice has been issued in accordance with Clause 4.8.3 in the NER.

The power system was in an insecure operating state immediately following the trip of the two 275 kV lines. The AEMO realtime network analysis applications indicated a number of security violations after the lines tripped. AEMO invoked outage constraint set S-RBPA+RBTU+RBTX designed to manage power system security with prior outages of the Robertstown – Para and Robertstown – Tungkillo 275 kV lines and the Robertstown T2 275/132 kV transformer. Some constraint equations in this constraint set bound immediately and constrained generation and interconnector flow. This had the effect of initially reducing the power system security violations, however, the constraint set did not contain constraint equations to cover the following conditions:

- Maintain the Waterloo East – Waterloo 132 kV line flow within ratings on the loss of the Davenport – Bungama 275 kV line.
- Maintain the Robertstown T1 275/132 kV transformer loading within ratings on the loss of either the Davenport – Bungama or Davenport – Brinkworth 275 kV lines.

The constraint set did not contain a constraint equation for the loss of the Davenport – Bungama or Davenport – Brinkworth 275 kV line because:

- AEMO had removed the Robertstown – Para and Robertstown – Tungkillo 275 kV lines from the ‘Vulnerable Transmission Lines’ list on 17 December 2010, and hence there was a very low probability of invoking the constraint set.
- A multiple outage has not been planned for the Robertstown – Para and Robertstown – Tungkillo 275 kV lines at the time that would have required AEMO to update the constraint set.
- The review of multiple outage constraint sets is a relatively low priority task for AEMO due to the very low probability of needing to invoke such sets, and AEMO’s constraint automation tool is available to use if such cases occur.
- ElectraNet has not provided AEMO with limits advice that include the relevant elements and contingencies for this multiple outage set.

At around 1220 hrs the severity of the security violations began to increase for the Waterloo East – Waterloo 132 kV line and the Robertstown T1 275/132 kV transformer contingencies as a result of not including the above constraint equations in the invoked constraint set. In response, AEMO used its constraint automation tool to build new constraint equations and, on AEMO’s suggestion, ElectraNet reconfigured the network to manage these power system security violations. At 1239 hrs AEMO invoked constraint set CA_BPS_3C672E99 built to prevent post-contingency overloading of the Waterloo East – Waterloo 132 kV line on the loss of the Davenport – Bungama 275 kV line. It took a further 14 minutes to remove the security violation on the Waterloo East – Waterloo 132 kV line. Between 1159 hrs and 1253 hrs the Waterloo East – Waterloo 132 kV line flow would have exceeded its line rating for the loss of the Davenport – Bungama 275 kV line and hence the power system was in an insecure operating state for that 54 minute period.

The Angaston generating units No.1 and 2 33kV circuit breakers 4552 and 4555 at ETSA Utilities Angaston 33kV substation opened simultaneously with the trip of the Robertstown – Para and Robertstown – Tungkillo 275 kV lines. The Angaston generating units were not generating at this time. ETSA Utilities has identified that these circuit breakers tripped due to the protection relays detecting an unacceptable rate of change of system frequency.

5 Conclusions

A lightning strike resulted in simultaneous faults on the Robertstown – Para and Robertstown – Tungkillo 275 kV lines. Both faults were cleared within the requirements specified in the NER. Approximately 170 MW load loss was observed in SA due to this incident and gradually recovered within approximately 20 to 25 minutes. The lines were patrolled and returned to service within 3.5 hours.

The power system was in an insecure operating state for 54 minutes after the lines tripped. Power system frequency remained within the normal operating frequency band. AEMO and ElectraNet took appropriate actions to maintain the power system in a satisfactory⁷ operating state following this non-credible contingency event.

Designed to maintain power system security with prior outages of Robertstown – Para and Robertstown – Tungkillo 275 kV lines and the Robertstown T2 275/132 kV transformer, constraint set S-RBPA+RBTU+RBTX did not have all the relevant constraint equations necessary to maintain power system security. AEMO consequently used its on-line constraint automation tools to build the relevant constraint equations to manage the power system security violations.

In accordance with its procedures, AEMO added the Robertstown – Tungkillo and Robertstown – Para 275 kV double circuit transmission lines to its list of ‘Vulnerable Transmission Lines’ with a category of ‘Probable’.

The Angaston generating units No.1 and 2 33 kV circuit breakers 4552 and 4555 inadvertently opened simultaneously with the trip of the Robertstown – Para and Robertstown – Tungkillo 275 kV lines. ETSA Utilities has commenced investigations into the cause.

6 Recommendations

1. ETSA Utilities will investigate the cause of the trip of the Angaston generating units No.1 and 2 33 kV circuit breakers 4552 and 4555, review the protection relay settings if necessary to avoid tripping due to a fault on the Para – Robertstown and Robertstown – Tungkillo 275 kV lines, and report their findings to AEMO, by 31 August 2011.
2. ElectraNet and AEMO will treat the trip of Angaston generating units No.1 and 2 as a part of the credible contingency event of the simultaneous trip of the Para – Robertstown and Robertstown – Tungkillo 275 kV lines during lightning activity in the area. This classification will be in place until ETSA Utilities advises ElectraNet and AEMO of revised protection relay settings that will avoid this simultaneous trip. ETSA Utilities will complete this action by 31 August 2011.
3. ElectraNet will send a copy of its investigation report to AEMO on back-flashover rate versus tower footing resistance and shielding wire failure, by 31 July 2011.
4. In light of this incident, AEMO will review the use of constraint automation with a view to reducing the time taken to bring the power system to a secure operating state. AEMO will complete this task by 31 July 2011.

⁷ Refer clause 4.2.2 in the NER