NEMMCO

National Electricity Market
Management Company Limited
ABN 94 072 010 327

# Power System Incident Report - Friday 13 August 2004

*Prepared by:* *System Operations Planning & Performance*

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**FINAL REPORT**

## Overview

On the evening of Friday 13 August 2004 at 21:41 hrs, a current transformer at Bayswater power station in New South Wales developed an internal fault causing it to later explode. This failure triggered a major power system incident which involved the loss of five large generating units and one medium capacity generating unit in New South Wales.

The sudden loss of generation caused the power system frequency to fall to 48.9 Hz, which then resulted in approximately 1500 MW of under-frequency load shedding (UFLS). This load shedding occurred in Queensland, New South Wales, Victoria and South Australia. This automatic load disconnection together with the combined response from the remaining generating units successfully controlled the power system frequency and prevented a major power system collapse.

NEMMCO published a preliminary report on 19 August 2004 which provided an initial assessment of the events based on information available to NEMMCO at that time. Subsequently, a further report on the load shedding that took place during the incident was published on 12 October 2004 to provide more information about the operation of the under-frequency load shedding facilities.

This report provides more detailed information on the cause of the incident and assesses the overall performance of the power system. This report is based on information obtained from NEMMCO's monitoring facilities, as well as information provided to NEMMCO by market participants and network service providers.

All times referred to in this report are in 'Market time', or Eastern Standard Time.

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## 1. Summary Of The Incident

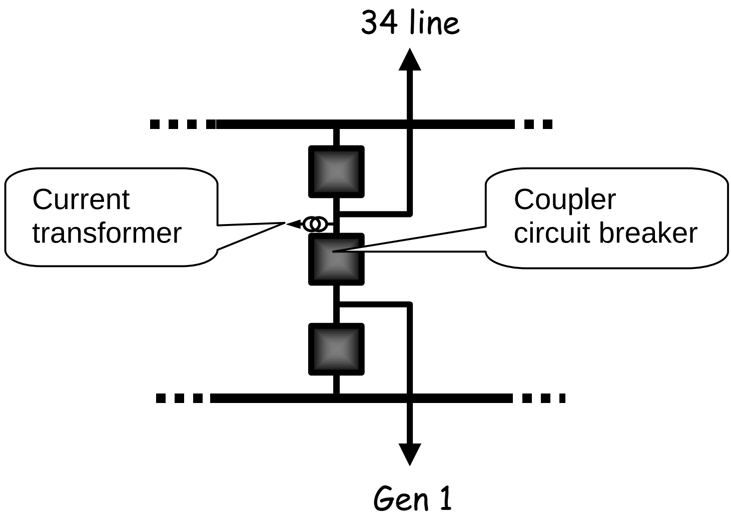
At 21:41 hrs on Friday 13 August 2004, a current transformer in the number 1 bay at Bayswater Power Station switchyard failed and later exploded. The number 1 bay at Bayswater Power Station switchyard contains three 330 kV circuit breakers which connect the 34 line to Liddell Power Station, and the number 1 generating unit at Bayswater Power Station, as indicated in figure 1-1.

### 1.1 Transmission and initial generation tripping

TransGrid has advised NEMMCO of the information contained in this section unless otherwise noted.

The current transformer that failed was a red phase unit adjacent to the coupler circuit breaker in the number 1 bay.

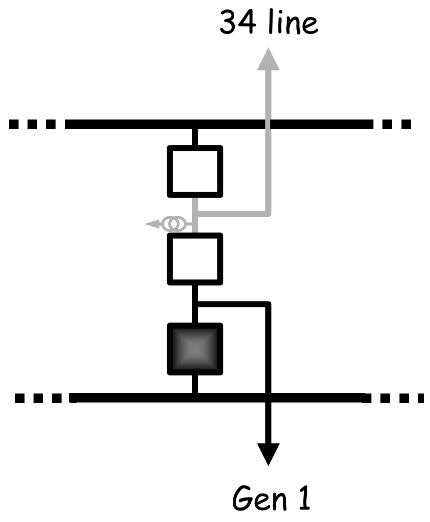
**Figure 1-1: Number 1 bay of Bayswater 330 kV Switchyard**[1]




The fault on the current transformer was detected by the protection systems on the 34 line, which acted automatically to open the 34 line circuit breakers both at Bayswater Power Station and at Liddell Power Station. The fault was cleared in 83.5 msec, which is within design expectations. The current transformer fault was then isolated from the power system by the open circuit breakers at Bayswater Power Station as indicated in figure 1-2, and at Liddell Power Station.

[1] The other Bayswater generating units are similarly configured.

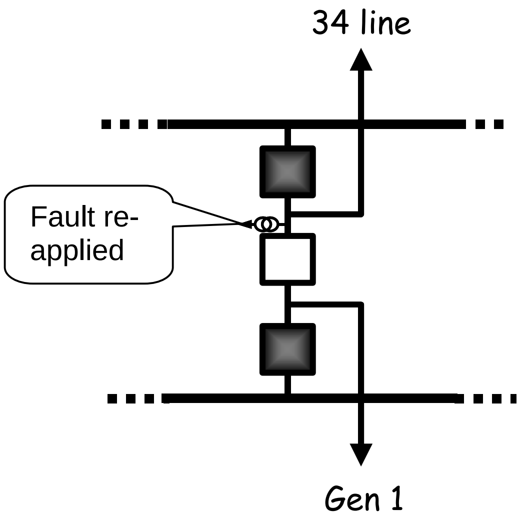
**Figure 1-2: Fault cleared by 34 line protection**




The protection systems on the 34 line from Bayswater Power Station to Liddell Power Station include auto-re-close facilities[2].

15 seconds after the initial fault, the auto re-close on the 34 line operated as designed and automatically closed the main bus circuit breaker as indicated in figure 1-3.

**Figure 1-3: Main bus circuit breaker auto re-close**




The fault on the current transformer was still present, and the auto re-close of the main bus circuit breaker resulted in the fault being re-applied to the power system for a second time.

[2] An auto-reclose facility initiates the reclosure of a circuit breaker that has opened following the operation of a protection system. These facilities are installed on most major transmission lines as the great majority of faults on transmission lines are of a short duration, often due to bushfires or lightning. Auto re-close then ensures that the transmission network is restored to full capacity as soon as possible. A lock-out function is often incorporated and this inhibits subsequent reclosure action following an unsuccessful reclosure attempt where the fault is still present.

The fault on the current transformer was again detected by the protection systems on the 34 line, which acted automatically to re-open the 34 line main bus circuit breaker at Bayswater Power Station. This second fault was cleared in 78.5 msec, which is within design expectations.

Having attempted an unsuccessful auto re-close on the main bus circuit breaker, this particular circuit breaker was then locked out, preventing it from any further auto re-close attempts.

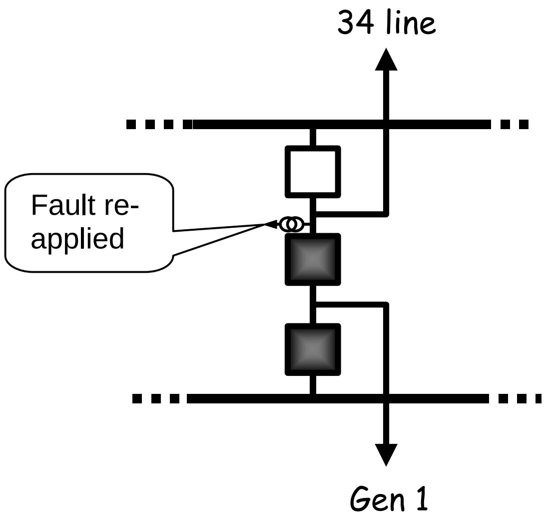
At the time of this auto re-close and second fault, Bayswater generating units 1, 2 and 3 all tripped automatically whilst generating 658 MW, 654 MW and 659 MW respectively. Macquarie Generation has advised that the three Bayswater generating units tripped on generator differential protection. Bayswater generating unit 4 remained synchronised to the power system.

Also at this time, Eraring unit 2 commenced an automatic shutdown sequence from 424 MW. Eraring Energy has advised that the shutdown of this unit was initiated by its negative phase sequence protection.

This sudden loss of generation caused the power system frequency to fall rapidly and within approximately 6.5 seconds, was down to 48.9 Hz (see figure 1-5). The frequency then began to recover as automatic under frequency load shedding commenced across Queensland, New South Wales, Victoria and South Australia.

16 seconds after the initial fault, the auto re-close on the 34 line operated to automatically close the coupler circuit breaker as indicated in figure 1-4. The auto-reclosure performed as designed, but one of the scheme's intended features (inhibiting the closure of the coupler circuit breaker reclosure following an unsuccessful reclose attempt using the line circuit breaker) was not effective. TransGrid has advised that action has now been taken to eliminate reclosure of coupler circuit breakers following an unsuccessful reclosure of the line circuit breaker, at the Bayswater Power Station switchyard, and at other similarly configured switchyards in New South Wales.

**Figure 1-4: Coupler circuit breaker auto re-close**



As the fault on the current transformer was still present, the auto re-closure of the coupler circuit breaker resulted in the fault being re-applied to the power system for a third time. This third application of the fault did not contribute to further automatic under-frequency load shedding.

The fault on the current transformer was again detected by the protection systems on the 34 line, which acted automatically to re-open the coupler circuit breaker at Bayswater Power Station switchyard. This third fault was cleared in 63.0 msec, which is within design expectations.

Having attempted an unsuccessful auto re-close on the coupler circuit breaker, this particular circuit breaker was then locked out, preventing it from any further auto re-close attempts.

No auto re-close attempts were made from the Liddell Power Station end of the line, as the protection is designed to only close the circuit breakers at Liddell Power Station once the line has been successfully energised from Bayswater Power Station.

## 1.2 Further Generation Loss

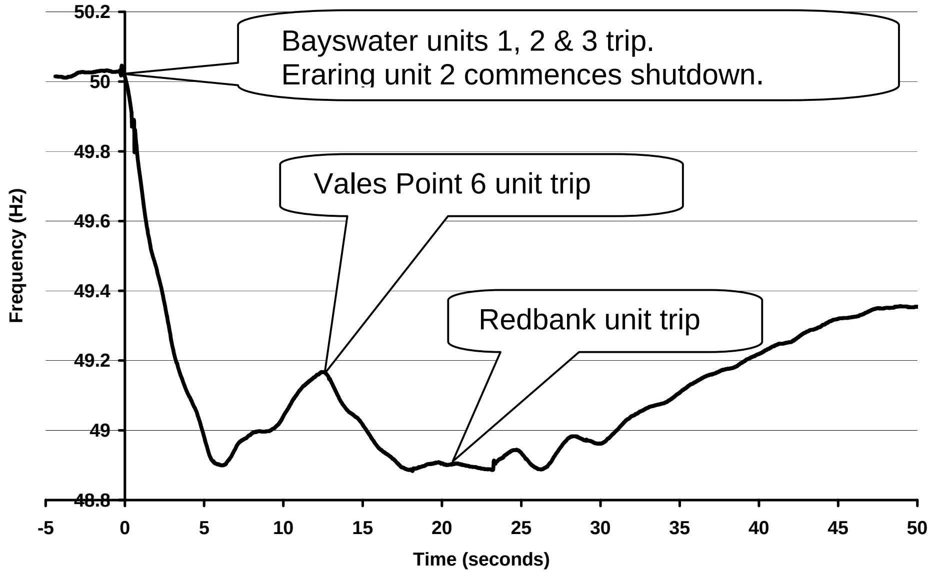
27 seconds after the initial fault, the Vales Point unit 6 tripped automatically from 542 MW. Delta Electricity have advised that the unit tripped on automatic voltage regulator protection, and that the Bayswater current transformer fault should not have caused the Vales Point generating unit 6 to trip.

Approximately 28 seconds after the initial fault, the Eraring generating unit 2 had completed it’s shutdown sequence, and was automatically disconnected from the power system.

When Vales Point unit 6 tripped, the power system frequency, which had been increasing due to the under frequency load shedding, began to fall again. The frequency continued to fall to a minimum value of 48.87 Hz, resulting in additional amounts of under-frequency load shedding.

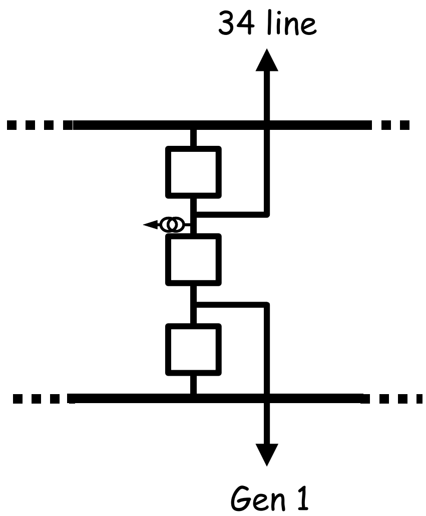
Approximately 36 seconds after the initial fault, the Redbank generating unit automatically tripped from 150 MW. Redbank Project Pty Ltd have advised that the unit protection was set to trip when the power system frequency was below 49.0 Hz for more than 6 seconds, and that this had caused the unit to trip.

**Figure 1-5: Power System Frequency**




At one minute, 58 seconds after the initial fault, the Bayswater number 1 generating unit transformer circuit breaker opened as shown in figure 1-6. TransGrid have advised that this circuit breaker opened due to inter-zone protection as a result of a new fault. Although TransGrid has not been able to exactly determine the location of this new fault, they are of the view that the opening of the Bayswater number 1 generating unit transformer circuit breaker was caused by an explosion and subsequent fire in the switchyard that was due to the original current transformer failure.

**Figure 1-6: Generating unit 1 circuit breaker open**




Note that as the number 1 generating unit at Bayswater had already tripped, this circuit breaker event did not impact on generation output.

### 1.3 Generation Return to Service

The generating units all returned to service during the following two days as follows:

- Vales Point unit 6 03:57 hrs 14 August 2004
- Redbank 04:28 hrs 14 August 2004
- Bayswater unit 3 06:01 hrs 14 August 2004
- Eraring unit 2 20:20 hrs 14 August 2004
- Bayswater unit 2 20:46 hrs 14 August 2004
- Bayswater unit 1 08:59 hrs 15 August 2004

## 2. Current Transformer Failure

This section gives an overview of the nature of the current transformer failure that occurred at Bayswater on the 13 August 2004, and then compares this to recent current transformer failures that have occurred at Tarong in Queensland on 18 November 2003 and at Jeeralang in Victoria on 12 April 2004.

### 2.1 Bayswater Event – 13 August 2004

TransGrid has advised NEMMCO of the following information.

TransGrid has carried out a range of investigations into the current transformer failure at Bayswater, however they have yet to conclusively determine the cause of the failure. They advised NEMMCO that in their view most of the evidence suggests failure in the earthing lead from the condenser bushing foil test terminal caused the current transformer to fail explosively.

The current transformer at the Bayswater switchyard was manufactured by Tyree Australia in the early 1980’s and is a conventional oil/paper insulated hairpin design. It has been in service since the commissioning of Bayswater switchyard in 1984. TransGrid is not aware of any specific operating conditions (either system or environmental) that are of such a severe nature at this site that they are likely to have contributed to the failure.

There were previous incidents at Bayswater in 1995 and 1998 involving the failure of 330 kV current transformers. Following those events in the mid to late 90’s, TransGrid installed monitoring facilities onto the current transformers, including the one that failed on 13 August 2004. It is understood that these monitoring facilities are to provide early warning of potential failure of the current transformers.

However, the failure that occurred on 13 August 2004 was of a different failure mode to those that occurred in the 90’s, and for this reason, the monitoring facilities that were installed did not provide early warning of the fault.

## 2.2 Tarong Event – November 2003[3]

Powerlink has advised NEMMCO of the following information.

On 18 November 2003 a current transformer within a circuit breaker failed at the Tarong sub-station in Queensland which caused the No. 1 275 kV bus at Tarong to trip and five 275 kV lines from Tarong to either trip or be off-loaded. The Tarong current transformer that failed was an ABB 300kV Type No: 06/300/18 twin-leg current transformer. The Tarong current transformer is different to the current transformer that failed at Bayswater on 13 August 2004 as the Tarong current transformer used an ABB Swedish insulation design which is quite different to the Bayswater current transformer which used an Australian Tyree design.

The Tarong current transformer was approximately 10 years old, having been manufactured in March 1993. It had been operated under normal loading conditions for a 300 kV current transformer, subjected to normal heating, voltage and surge stresses.

Powerlink investigations indicate the Tarong current transformer failure occurred about a quarter way up one of the twin legs of the current transformer. Due to extensive damage to the current transformer the cause of the failure could not be conclusively determined, but Powerlink's investigations suggest it was not age related.

## 2.3 Jeeralang Event – 12 April 2004[4]

SPI PowerNet has advised NEMMCO of the following information.

On the 12 April 2004, a 220 kV current transformer failed at Jeeralang. The current transformer at Jeeralang was a GEC type FMJL unit supplied in 1982.

The failed current transformer had only been in service for two years. SPI PowerNet carried out an investigation which considered switching surges, lightning, thermal overload, degradation with moisture, manufacturing error and design faults. They concluded that the most likely cause of the failure was that it was damaged during transit to the site in 2002.

SPI PowerNet have been conducting routine analysis of dissolved gas in oil (DGA) for current transformers for over 30 years and infra-red thermal scanning for over 20 years. Any adverse DGA results identified in that analysis are then investigated further. Leakage (capacitive) current monitoring devices, are being installed as a further on-line diagnostic analysis tool for selected current transformers.

SPI PowerNet have an extensive monitoring and replacement program for current transformers in place. The monitoring frequency and type of monitoring is changed as required for individual units in order to minimize the risk of failure. When a failure does occur it is investigated by SPI PowerNet and the monitoring and/or replacement plan changed as required.

[3] NEMMCO's report on this incident is available on the NEMMCO website at http://www.nemmco.com.au/marketandsystemevents/232-0018.htm. Refer also to NEMMCO Communication No.1492 – System Incident Report – 18 November 2003.
[4] NEMMCO did not prepare a report on this event.

### 2.4 Failure Modes

Based on the above information provided to NEMMCO by the relevant TNSP's, NEMMCO considers that the failure modes of the Bayswater event and two previous current transformer failures at Tarong and Jeeralang are not similar.

NEMMCO has been advised by the relevant TNSPs that it is common practice for the TNSP's to share important asset management information such as failure modes of high voltage equipment on a routine basis. NEMMCO supports such information interchange being maintained.

## 3. Six Generating Units Tripped – Why?

The failure of the current transformer at the Bayswater switchyard led to the loss of six generating units in New South Wales totalling 3100 MW. The loss of these six generating units resulted in a substantial frequency disturbance on the power system, which was then controlled through the action of automatic under-frequency load shedding and the combined response from the remaining generating units.

The following summarises the information that has been obtained to date:

### 3.1 Bayswater Units 1, 2 and 3

Macquarie Generation has advised NEMMCO as follows in this section 3.1 in respect of the Bayswater Units.

The Bayswater units 1, 2 & 3 were tripped by the operation of the generating units' differential protection relays. In Macquarie Generation's view this type of protection is intended to detect a fault within the generating unit itself, and should not trip for faults external to the generating unit. The current transformer at Bayswater switchyard that failed is well outside the protection zone for the Bayswater generating units' differential protection.

Macquarie Generation, in conjunction with Siemens and ABB (the original manufacturers of the protection equipment) have carried out a range of investigations to establish the cause of the unit trips, including:

- Re-creating the fault conditions by injecting simulated fault signals into the protection relays, similar to those that occurred on 13 August 2004. These tests did not reveal any problems with the protection relays.
- Testing and analysis on the differential protection relays, including harmonic testing to confirm relay sensitivities, phase angle modulation, standard secondary injection routine tests and confirmation of operating response under various fault conditions.
- Current transformer testing including saturation testing, magnetisation characteristics and inductance and resistance testing.

Macquarie Generation has been unable to determine an explicit cause for the operation of the generator differential protection relays to date. They have concluded that the generator differential protection system was set up as per the original specifications and have informed NEMMCO that the system remains in operation. Macquarie Generation is continuing its investigation into the cause of the protection operation.

### 3.2 Eraring Unit 2

Eraring Energy has advised NEMMCO as follows in this section 3.2 in respect of Eraring unit 2.

Eraring unit 2 was tripped by the operation of one of its two negative phase sequence ("NPS") protection systems. This type of protection detects an out of balance in the three phase voltages and normally only operates as a last resort to protect the generating unit against an external uncleared fault condition on the power system. The NPS protection is used in conjunction with a time delay so as to provide time grading to allow external protection systems to detect and clear the fault.

After the tripping of Eraring Unit 2, Eraring Energy performed preliminary investigations which revealed that the time delay function did not operate correctly on the Siemens NPS protection system and thus operated as soon as it detected the fault. Following the Eraring unit 2 trip on 13 August 2004, the faulty negative phase sequence protection system was de-activated to prevent a re-occurrence. The other negative phase sequence protection system remained in service to protect the unit.

Subsequently Eraring Energy took the unit out of service for a planned refurbishment and advised that the entire protection system was checked for any malfunctions.

These investigations revealed a faulty transistor in the timer circuit of the Siemens NPS relay. The faulty timer meant that should the NPS detect an external fault, the normal time grading would not have been effective and hence the protection could operate prematurely.

The faulty transistor has been replaced and the protection system checked and calibrated. Eraring Energy considers that this unit should now be regarded as fully reliable against this problem.

### 3.3 Vales Point Unit 6

Delta Electricity has advised NEMMCO as follows in this section 3.3 in respect of Vales Point Unit 6.

The Vales Point unit 6 tripped when the generating unit automatic excitation regulator (AER) drove the unit to a low level of excitation at which point, in Delta Electricity's view, the generating unit protection systems correctly operated. Delta Electricity were able to retrieve some diagnostic data from the fault recorders, and that this data was provided to the manufacturer for analysis.

Extensive testing of the AER carried out during November was unable to identify a cause for the maloperation, however Delta Electricity concluded that the generating units power system stabilisers were not responding. Subsequent to this conclusion, Delta Electricity consulted with TransGrid and

Delta Electricity determined to switch the Vales Point unit 5[5] and unit 6 power system stabilisers off until additional tests are undertaken. NEMMCO was informed that the stabilisers had been turned off, but NEMMCO does not accept this as a permanent solution.

On the basis of advice provided by Delta Electricity, NEMMCO considers that during the interim, the unavailability of the power system stabilisers at Vales Point unit 5 and unit 6 is not likely to have a significant impact on the power system. NEMMCO understands that Delta Electricity is planning to carry out further investigative work during 2005 into the performance of the unit AER.

### 3.4 Redbank Unit

Redbank Project Pty Ltd has advised NEMMCO as follows in this section 3.4 in respect of the Redbank unit.

The Redbank unit has an under frequency protection relay that is set to trip the unit when the power system frequency falls to 49.0 Hz or lower for a duration of 6 seconds. During the system incident on 13 August 2004, the frequency initially fell below 49.0 Hz approximately 6 seconds after the Bayswater units tripped, but recovered to above 49.0 Hz in approximately 4 seconds. The Redbank unit under frequency protection relay did energise during this initial frequency excursion, but the relay timer did not achieve a duration of 6 seconds and hence the relay did not activate.

Redbank Project Pty Ltd has determined that when the frequency fell for a second time[6], the frequency remained below 49.0 Hz for a longer period of time that exceeded the duration setting of the relay timer and the Redbank unit subsequently tripped on under frequency protection.

Redbank Project Pty Ltd have stated that they intend to modify their under-frequency trip settings dependent on agreement from the generating unit manufacturer that equipment is capable of withstanding the changed trip settings. Redbank Project Pty Ltd has indicated that they expect to be able to modify their settings in April 2005 during a planned outage.

## 4. Interconnector Flows

Immediately after the loss of generation in New South Wales, all interconnector transfers into New South Wales increased by large amounts as reserves were called upon to stabilise the system. Generation reserves from Snowy, Victoria and Queensland all contributed to make up the deficit in New South Wales. Table 1 below summarises the MW transfers on each of the interconnectors immediately prior to the event, the maximum flow during the incident, the level 10 minutes after the incident at approximately 21:52 hrs and the transfer limit.

[5] Vales Point unit 5 has the same type of power system stabiliser as Vales Point unit 6.
[6] The frequency fell for a second time following the trip of Vales Point unit 6.

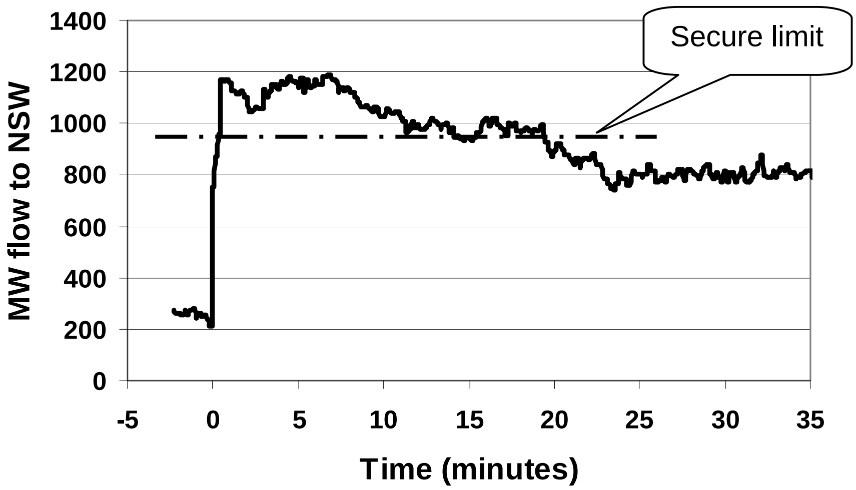
**Table 4-1: Interconnector Flows**

| Interconnector | Initial (MW) | Maximum (MW) | After 10 min (MW) | Limit (MW) |
|---|---|---|---|---|
| QNI to NSW (AC) | 213 | 1188 | 1040 | approx 950 |
| Directlink to NSW | 0 | 0 | 0 | |
| Snowy to NSW | -15 | 1313 | 1313 | approx 3000 |
| VIC to Snowy | -100 | 905 | 660 | approx 760 |
| SA to VIC (AC) | -460 | -241 | -460 | approx -460 |
| Murraylink to VIC | -80 | -3 | -3 | |

## 4.1 Queensland – New South Wales Interconnector

Following the loss of the generation in New South Wales, the power transfer on QNI increased from 213 MW to 1188 MW towards New South Wales, as shown in figure 4-1.

**Figure 4-1: QNI Power Flow**




Immediately following the loss of the New South Wales generating units, the power transfer from Queensland to New South Wales was above the secure limit[7] of 950 MW. NEMMCO believes (on the basis of the analysis discussed below) that in this insecure state, any further loss of a large generating unit south of the Queensland – New South Wales border could have resulted in QNI tripping and the separation of Queensland from the other NEM regions. The QNI transfer was restored to a level within the secure limit in about 15 minutes, which is within the 30 minutes objective as established in the Code.

[7] The limit is advised by the Inter-Regional Planning Committee (IRPC).

Simulation studies undertaken by NEMMCO indicate that had the QNI transfer exceeded about 1350 MW, the interconnector would be expected to have tripped resulting in the separation of Queensland from the rest of the power system. The separation would be due to voltage collapse arising from a requirement for the static var compensators (SVC) at Braemar and Armidale to exceed their reactive supply limits. Normal operating practice is to switch static reactive devices to ensure that the dynamic reactive range of generating units and SVCs is maximised. Before the incident, the SVCs' outputs were; – 20 MVAr at Armidale and 5 MVAr at Braemar. With the transfer at 1350 MW, the SVCs maximum capabilities of 280 MVAr at Armidale and 150 MVAr at Braemar would have been fully used with consequent separation of the interconnector due to voltage collapse.

The high QNI transfer during this incident was a result of the multiple generating unit contingency event and subsequent under- frequency load shedding.

With events such as this, it is very difficult to predict the outcome with any accuracy. If the generating unit response and load shedding had differed slightly, the result may have been very different. For example, had the Vales Point generating unit not tripped, then the frequency would have continued to recover after the initial excursion to 48.9 Hz, and possibly at least 300 MW of load in Queensland may not have been shed. The Redbank generating unit may also not have tripped.

It would be very difficult to operate the power system in such a way to avoid post contingent overloading on all interconnectors following multiple contingencies, without operating the network to very conservative limits, or establishing much more sophisticated control schemes.

Powerlink has suggested that further measures should be taken to reduce the risks of QNI tripping at very high southward power flow following multiple contingency events. Measures could include blocking certain under-frequency actions in Queensland (without interfering with the existing high speed under frequency load shedding scheme in Queensland) if QNI flow exceeds a preset value.

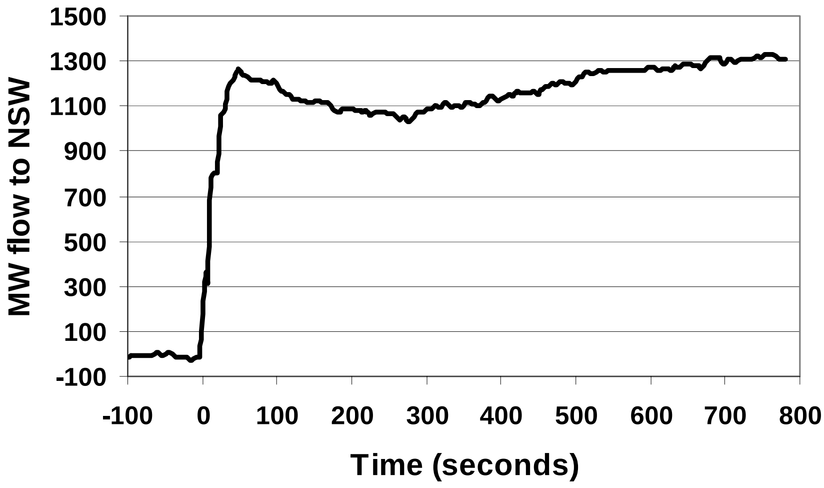
The proposal from Powerlink will be considered either as part of the investigation of the NEM wide under-frequency load shedding arrangements initiated by NEMMCO or other appropriate review. Pending completion of the load shedding review, NEMMCO does not at this time favour the inclusion of conditional inhibit facilities on existing under frequency load shedding, as this is the safety net for the protection of the power system, and accordingly must be as reliable, and as robust as possible.

The power flow on Directlink immediately prior to the loss of generation in New South Wales was 0 MW. At 21:55 hrs Directlink received a target from the NEM systems to increase power flow to 80 MW to New South Wales, and at 22:00 hrs, the flow on Directlink started to increase. By 22:11 hrs, Directlink was transferring 115 MW from Queensland to New South Wales.

### 4.2 Snowy – New South Wales Interconnector

The power transfer from Snowy to New South Wales increased from approximately 0 to 1300 MW as indicated in figure 4-2. This was within the transfer capability of this interconnector which was approximately 3000 MW at that time.

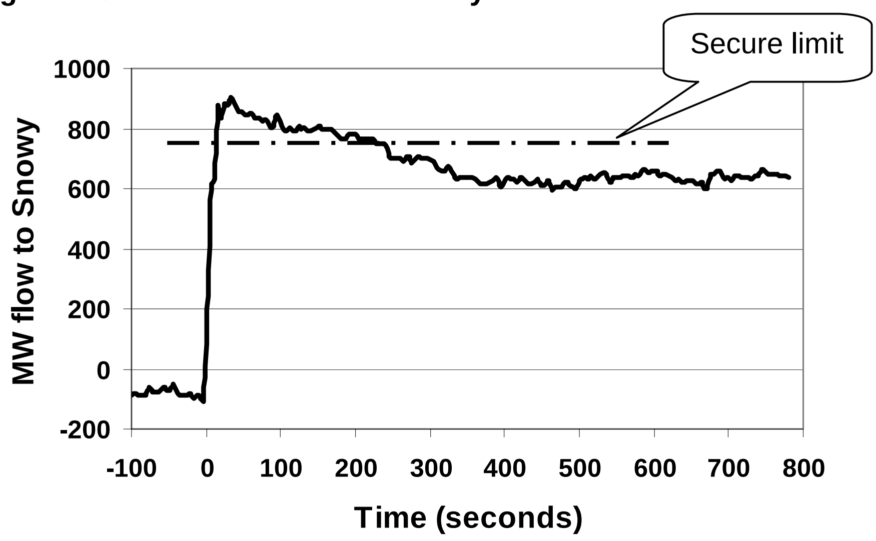
**Figure 4-2: Power flow Snowy to NSW**




### 4.3 Victoria to Snowy

The power transfer on the Victoria to Snowy interconnector increased from –100 to 905 MW, which was over the secure limit at the time of 760 MW. The power transfer on this interconnector was reduced below it's secure level in a little under 4 minutes, which is within the Code requirement of 30 minutes.

**Figure 4-3: Power Flow Vic to Snowy**




## 5. Frequency Control Ancillary Service

Frequency control ancillary services (FCAS) are procured by NEMMCO to ensure that the frequency remains within the frequency operating standard for credible contingency events, such as the loss of a single generating unit. NEMMCO does not specifically enable FCAS to cater for non-credible events including multiple contingency events, as the likelihood of multiple contingencies is very low, and the costs would be very high.

However when a multiple contingency event such as this occurs, it is never the less important to analyse how the enabled FCAS services performed. The large deficit of generation following the incident meant that all enabled FCAS service providers were called upon to provide maximum support possible. Table 5-1 summarises the amount of FCAS enabled and the response delivered in the 5 minute period starting 21:40 hrs. The delivered amounts exclude response from loads that were tripped by under-frequency load shedding, as these are not considered to be FCAS.

**Table 5-1: Summary of FCAS provided**

| | Fast (6 sec) raise | | Slow (60 sec) raise | | Delayed (5 min) raise | |
|---|---|---|---|---|---|---|
| | **Delivered** | **Enabled** | **Delivered** | **Enabled** | **Delivered** | **Enabled** |
| Vic | 69 | 95 | 183 | 80 | 181 | 118 |
| Qld | 146 | 75 | 641 | 92 | 206 | 119 |
| NSW | 268 | 69 | 531 | 67 | 225 | 90 |
| SA | 124 | 36 | 195 | 15 | 27 | 30 |
| Snowy | 5 | 0 | 294 | 0 | 281 | 120 |

It can be seen that for almost all cases the service delivered was well above the service enabled. This is expected, as the FCAS enabled is the amount required to respond to a single large generation unit trip. In this case however, there were 6 large generating units that tripped, which triggered a much larger response.

The large amount of service delivered was generally as a result of generating unit governor actions due to the large frequency drop following the incident. This FCAS response together with the load relief due to the low frequency supported the under-frequency load shedding in containing, stabilising and recovering the power system frequency. The power system frequency was maintained within the frequency operating standards.

From the initial frequency deviation of 48.9 Hz, the power system frequency increased to 49.15 Hz over a period of approximately 6 seconds. The subsequent loss of 542 MW of generation at Vales Point resulted in the system frequency falling. By then, most available FCAS capacity from the enabled units had been expended. Further FCAS could not be enabled until the next 5 minute period. NEMMCO's view is that this second fall in the frequency was significant in delaying the eventual recovery of the frequency back to it's normal operating band.

Where non-conformance is identified, NEMMCO will follow-up with the relevant service providers.

## 6. Operational and Stakeholder Communication

The under-frequency load shedding that resulted from this event combined with the media interest in electricity supply issues gave rise to the need for rapid communication with stakeholders and the media. The nature of the load shedding meant that most of the media and stakeholder focus was in Queensland, requiring rapid provision of information.

The communication process as set out in the NEM Emergency Protocol describes the communication of information between Responsible Officers. During the event some Responsible Officers experienced delays in making contact with each other by mobile phone, which resulted in time delays in the sharing of information. This time delay did not in any way impact on the power system operation or the restoration of the load, as these functions are carried out by separate on line operations staff.

NEMMCO has carried out a review of Responsible Officer communication arrangements and has now developed a system of SMS messaging and a prearranged teleconferencing facility to enable the rapid dissemination of information to Responsible Officers during all hours.

## 7. Market Pricing

At all times during this event market prices were determined in accordance with the Code. The Code provides that when load is shed as a result of a contingency, the VoLL flag should be not be set until the third dispatch interval following restoration to a secure operating state and the restoration of the frequency of the power system to the normal band of the frequency operating standards. A secure operating state was achieved at 21:47 hours, frequency was restored to the normal operating band at 21:47 hours and load restoration commenced at 21:56 hours. Thus the VoLL flag was not required to be set at any stage during this event.

## 8. Conclusions

On the basis of the information provided by TransGrid to NEMMCO, NEMMCO is of the view that the initial fault and subsequent auto re-close operations due to the current transformer failure at Bayswater substation were cleared correctly within the designed protection time.

In this incident the Bayswater and Eraring generating units that tripped withstood the initial fault but not the fault reapplied following the automatic reclosure. Although it is common and widespread practice to automatically reclose circuit breakers following line faults, the Code provision relating to generating units withstanding faults, clause s5.2.5.3(a)(3), does not contemplate reclosure. NEMMCO considers reclosure onto a sustained fault reasonably possible wherever automatic reclosure facilities are fitted. The current Code requirements and the resulting situation appears, in NEMMCO's view, to be inconsistent with the principle that credible contingency events should not cause cascading outages. NEMMCO considers that the ability of a generating unit to withstand faults reapplied by reclosure in the network is of such importance to power system security, that this requirement should be imposed on Generators.

NEMMCO notes that clause 4.15 of the Code now requires Code Participants to notify NEMMCO if their plant is unable to meet its performance standards, to undertake remedial action within a period determined by NEMMCO and to inform NEMMCO when the plant again meets its performance standards. The performance standards were not registered for the affected units at the time of the incident, but have now been registered for Bayswater, Eraring and Vales Point units. To the extent that the relevant performance standards deal with withstanding faults, it will be of importance to NEMMCO that the compliance programs to be submitted under clause 4.15(b) adequately address this issue.

Following the occurrence of significant power system events it is critical that shortly following the event, NEMMCO is able to quickly and effectively obtain information from the relevant parties to assess the risks to overall power system security and for rapid follow-up. The Code currently provides for this information to be provided to NEMMCO but there are no time limits specified for the provision of this information.

While NEMMCO is satisfied that the four generating companies in New South Wales have responded reasonably in commencing investigation processes, NEMMCO does not have any basis under the Code for:

(a) Requiring Generators to commence such an investigation process or,

(b) Requiring Generators to provide NEMMCO with an assurance that their generating unit can withstand a credible contingency event. It is fundamental from a power system security perspective that NEMMCO be in a position to determine that the system is capable of withstanding credible contingency events and, if it is not, that action can be taken to rectify the matter.

Although, under-frequency load shedding performed satisfactorily in restoring system frequency, it is now understood that the load shedding was not well shared between regions. NEMMCO has begun reviewing the load shedding across the NEM and is in the process of engaging a consultant to assist with this review in accordance with an agreed set of principles. NEMMCO will consider the possible implementation of measures to manage the flows on interconnectors to prevent regions from islanding following multiple contingency events, and if so, the extent to which any such measures may impact on under-frequency load shedding.

## 9. Recommendations

- The Code provisions relating to automatic reclosure, generating unit technical standards and incident investigation should be urgently reviewed, as follows:
    - The role of automatic reclosure in relation to power system security and the obligations on Network Service Providers and Generators should be reviewed to ensure that generating units are required to withstand faults reapplied by reclosure in the network.
    - Where a Code Participant is required to provide information to NEMMCO for the purposes of an investigation under clause 4.8.15 and the Code Participant's plant tripped, the Code Participant should be required to undertake an investigation of the plant's performance and report to NEMMCO within a reasonable time, say 20 business days.
- The under-frequency load shedding arrangements across the National Electricity Market should be reviewed. (Refer to the attached report in

Appendix A. NEMMCO has initiated a review of the under-frequency load shedding arrangements.)

- Macquarie Generation and Delta Electricity should complete their investigations into the reasons why their respective generating units tripped, and provide NEMMCO with:

  (a) details of the conclusions in their reports and,

  (b) assurances that their generating units can withstand disturbances following credible contingency events that are cleared in primary protection time and with subsequent auto-reclosure onto a fault.

- Redbank Project Pty Ltd should amend their under frequency tripping settings as soon as practicable and provide NEMMCO with an assurance that their generating unit can withstand frequency disturbances within the limits of the frequency operating standards.

- NEMMCO should review and improve the arrangements for Responsible Officer communications following major system incidents. (This has been completed).

## Appendix A – Under Frequency Load Shedding

The following is a copy of the report published by NEMMCO on 12 October into the under frequency load shedding that resulted from the incident on 13 August 2004. Compared with the previously published report, the name of the Distribution Network Service Provider in ACT has been corrected.

NEMMCO

**National Electricity Market Management Company Limited**
ACN. 072 010 327

# Power System Incident Report - Friday 13 August 2004

# Load Shedding Report

| | |
|---|---|
| *Prepared by:* | *System Operations Planning and Performance* |
| *Version No:* | *2.0* |
| *Date:* | *28 January 2005* |

# 1 INTRODUCTION

This report is to give an assessment of the load shedding that occurred during the major power system disturbance that occurred on Friday 13 August 2004.

NEMMCO published a preliminary report on the disturbance on 19 August 2004, and is preparing a more detailed incident report, which is expected to be finalised in November.

This additional report on load shedding is being published in advance of the final report to address specific questions concerning the operation of the under-frequency load shedding facilities. It is prepared on the basis of information at hand on the date of publication, and will be subject to review before inclusion in the final incident report.

# 2 SUMMARY OF THE DISTURBANCE

At 21.41 hrs an equipment failure at the Bayswater Power Station switchyard in the Hunter Valley NSW resulted in a 330 kV transmission line tripping out of service, and this was subsequently followed by six major generating units tripping out of service. The total generation loss was about 3 100 MW or about 14% of total supply in the National Electricity Market.

The fault was rapidly cleared by protection and an automatic re-closure occurred on each of the two line circuit breakers at Bayswater about 15 and 16 seconds later to attempt to restore the transmission line. Generation tripping commenced around the time of the first circuit breaker automatic re-closure onto the fault, causing the power system frequency to fall rapidly to approximately 48.9 Hz across the entire power system. Further generating unit tripping occurred about 13 seconds later. To correct the frequency, a total of about 1500 MW of load was automatically disconnected across Queensland, New South Wales, Victoria and South Australia. Generating unit response, low frequency load relief and other customer load loss due to voltage disturbances made up the 1600 MW deficit of generation.

This preliminary investigation has found that, the load shedding largely operated as designed, and frequency was restored in accordance with the frequency operating standards. However, the sharing of shedding between regions was not well balanced for this particular event.

# 3 UNDER-FREQUENCY LOAD SHEDDING

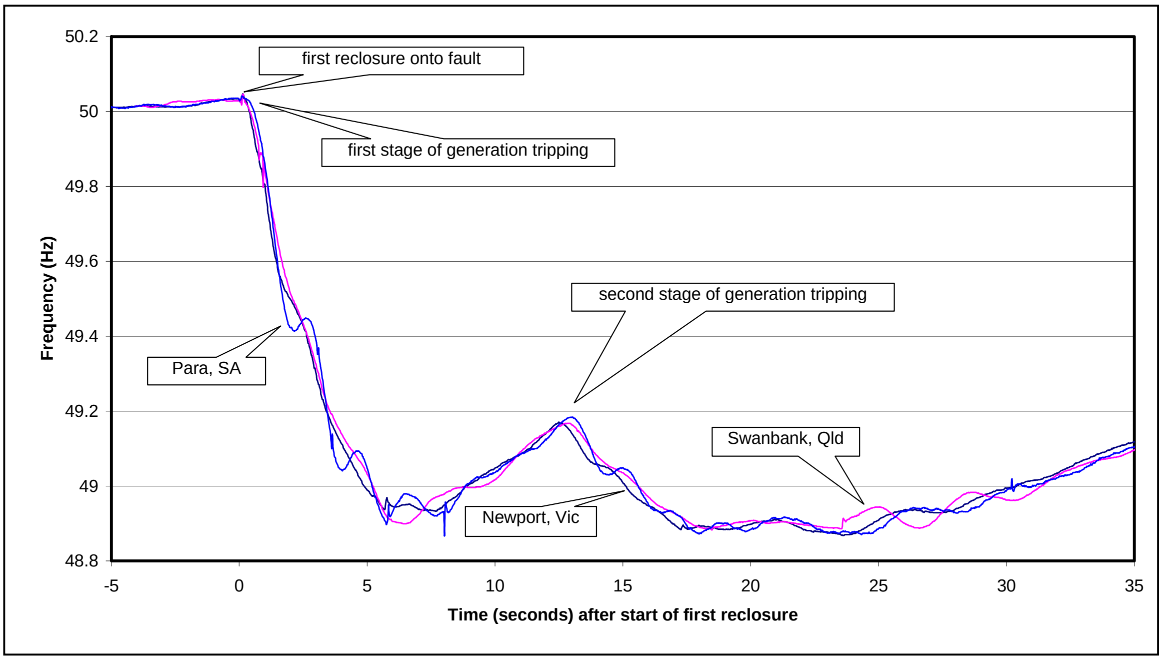
Clause 4.3.5 of the National Electricity Code requires Market Customers with load of more than 10 MW to make at least 60% of their load available for automatic under-frequency load shedding at frequencies within the range 47 to 49 Hz as nominated by NEMMCO. Under-frequency load shedding provided as a frequency control ancillary service is considered separately in section 5 below.

Based on information collected by NEMMCO at its control centres and information provided by Code Participants, the details of load shedding initiated automatically in response to the low power system frequency has been established as set out below. This assessment is based principally on NEMMCO's Energy Management System (EMS) records, supplemented with high speed records from other parties where available.

ElectraNet, VENCorp, and CSEnergy have provided high speed frequency records (with 20 ms time resolution) from Para, Newport and Swanbank respectively. These are graphed in Figure 1. Powerlink provided high speed frequency records for Blackwall (with 50 ms time resolution) similar to those for Swanbank. Similar records are available from Mount Piper Power Station, but have not been included in Figure 1 because they have considerable oscillation in the period 5 to 10 seconds, which would make the other traces more difficult to distinguish.

In Figure 1 and in the details provided below, time has been referenced to the start of the first reclosure onto the fault in the Bayswater switchyard. The first generation tripping occurred during this fault. A second stage of generation tripping occurred about 13 seconds later.

**Figure 1 Frequency during the disturbance**




The high speed measurements show that the frequency in different regions differ by up to about 0.05 Hz, and the times of minima vary by up to 6 seconds. The times of greatest difference between the Swanbank and Newport frequency traces are evidence of oscillation excited by the load shedding in Queensland. All measurements also show some small transients, which are thought to be due to measurement technique, possibly as a result of abrupt voltage variations.

The lowest frequencies measured in each region by these high speed records and NEMMCO's EMS records at the nearest capital city are shown in Table 1. The frequencies are rounded to three decimal places and the times are given relative to the start of the first of the automatic reclosures at Bayswater Power Station switchyard.

**Table 1 Summary of minimum frequencies**

| | First minimum (Hz) at time (sec) | | Second minimum (Hz) at time (sec) | |
|---|---|---|---|---|
| **Location** | **High speed** | **EMS** | **High speed** | **EMS** |
| Para | 48.897 @ 5.8 | - | 48.870 @ 24.3 | - |
| Newport | 48.933 @ 7.7 | 48.946 | 48.868 @ 23.6 | 48.908 |
| Swanbank | 48.899 @ 6.4 | 48.919 | 48.884 @ 18.5 | 48.887 |
| Mount Piper | 48.869 @ 7.0 | 48.948 | 48.874 @ 23.7 | 48.877 |

Table 2 summarises the under-frequency load shedding that occurred, presented in the sequence in which the shedding occurred. The times shown are relative to the start of the first reclosure, and based on an initial assessment of available information.

**Table 2 Summary of under frequency load shedding performance**

| Sequence | Time (sec) | Region | Reduction (MW) | Trip settings |
|---|---|---|---|---|
| 1 | 1.3 | SA | 17.6 | 49.6 Hz |
| 2 | 3.2 | NSW | 268 | 49.2 Hz |
| 3 | 5.3 | VIC | 119 | 49.0 Hz |
| 4 | 5.7 | VIC | 279 | 48.95 Hz |
| 5 | 5.7 | NSW | 93 | 48.95 Hz |
| 6 | 7.4 | QLD | 210 | 48.9 Hz |
| 7 | 16.5 | VIC | 90 | 48.9 Hz |
| 8 | 18.5 | NSW | 101 | 48.9 Hz |
| 9 | 23.6 | QLD | 307 | 49.0 Hz 8 sec delay |

In respect of the last item, the demand reduction from the interconnected power system was 307 MW, but as the disconnected network included some embedded generation, which tripped, the gross load loss was greater by an estimated 25 MW.

It should be noted that under-frequency load shedding usually operates immediately when the frequency is reliably detected below the trip frequency setting. The time to trip including the operating time of circuit breakers is usually much less than 1 second. However, in some cases, such as the last entry in the table above, a time delay is inserted.

### 3.1 Load 1 (South Australia)

This load was shed by operation of an under-frequency relay set at 49.6 Hz. ElectraNet SA has advised that the loading reduced by 17.6 MW, but has not provided any records to support that advice.

NEMMCO has no information that would suggest that the load shedding facility did not operate as designed.

This relay was set higher than required under National Electricity Code clause 4.3.5 because it had previously been used to provide frequency control ancillary services under contract, which required a frequency setting above 49.0 Hz. Although the contract terminated in 2001, the setting has not been changed.

### 3.2 Load 2 (New South Wales)

This load was reduced by operation of an under-frequency relay set at 49.2 Hz. NEMMCO's EMS records show that the loading reduced by 268 MW, but these records are not adequate to assess the precise time when the load was shed.

The Powerlink high speed frequency record shows a transient at 3.22 seconds after the first reclosure, when the frequency (in Queensland) was 49.239 Hz. This is consistent with this load being shed at that time.

This relay was set higher than required under National Electricity Code clause 4.3.5 because it had previously been used to provide frequency control ancillary services under contract, which required a frequency setting above 49.0 Hz. Although the contract terminated in 2001, the setting has not been changed.

### 3.3 Load 3 (Victoria)

This load was shed by operation of an under-frequency relay set at 49.0 Hz. NEMMCO's EMS records show that the loading reduced by 119 MW, but these records are not adequate to assess precise time when the load was shed.

High speed records provided by VENCorp for Newport Power Station switchyard show a transient 5.29 seconds after the first reclosure when the frequency was 48.975 Hz, which is likely to be a consequence of this load being shed. This suggests that the relay operated correctly.

### 3.4 Load 4 (Victoria)

This load was shed by operation of an under-frequency relay set at 48.95 Hz. NEMMCO's EMS records show that the loading reduced by 279 MW.

Based on high speed frequency records from VENCorp, the assessment indicates that this load shedding operated correctly at 5.74 seconds after the first reclosure, and 0.2 seconds after the frequency fell through 48.95 Hz.

### 3.5 Load 5 (New South Wales)

This load was shed by operation of an under-frequency relay set at 48.95 Hz. NEMMCO's EMS records show that the loading reduced by 93 MW at about the same time as the first load in NSW, but these records are not adequate to assess the precise time when the load was shed.

NEMMCO has no information that would suggest that the load shedding facility did not operate as designed.

### 3.6 Load 6 (Queensland)

This load was shed by operation of numerous under-frequency relays set at 48.9 Hz mostly within the distribution networks. Powerlink Queensland has advised NEMMCO that the load reduction was 210 MW, based on the load on the feeders just prior to the trip. NEMMCO's EMS records do not include this data.

The high speed measurement of the Tarong-Braemar line flow shows no clear change that could be evidence of this load shedding, but does show an oscillation of similar frequency to that which occurred after the shedding of the second block of Queensland load. This suggests that this block was shed near the time of the first frequency minimum. The minimum frequency at Swanbank at this time was 48.899 Hz, so tripping at this time or shortly thereafter was possible.

### 3.7 Load 7 (Victoria)

This load was shed by operation of an under-frequency relay set at 48.9 Hz. NEMMCO's EMS records show that the loading reduced by 90 MW about 12 to 16 seconds after the other Victorian loads, but these records are not adequate to assess under-frequency relay performance.

The high speed frequency records from Heywood and Newport show a transient at 16.48 seconds, which suggests that the load was shed at this time.

### 3.8 Load 8 (New South Wales)

This load was shed by operation of an under-frequency relay set at 48.9 Hz. NEMMCO's EMS records show that the loading reduced by 101 MW about 12 to 16 seconds after the other NSW loads, but these records are not adequate to assess under-frequency relay performance.

The high speed frequency record for Mount Piper shows that the frequency of 48.9 Hz was reached at 17.48 seconds after the first reclosure. The Swanbank high speed frequency record shows a slight transient at 18.5 seconds, which suggests that the load may have been shed at this time. The high speed measurement of the Tarong-Braemar line flow shows that the load shed at that time was not load shed in Queensland.

### 3.9 Load 9 (Queensland)

This load was shed by operation of numerous under-frequency relays set at 49.0 Hz with an 8 second time delay, mostly within the distribution networks. Powerlink Queensland has advised NEMMCO that the load reduction was 307 MW, based on the load on the feeders just prior to the trip. NEMMCO's EMS records do not include this data. Powerlink has also advised that several generating units embedded in the distribution network tripped when disconnected from the main power system, and that an equivalent amount of load was also therefore lost, estimated by Powerlink to be 25 MW. Thus the total load lost was about 332 MW.

Based on Powerlink's high speed frequency record, the 8 second timer would have started at 5.22 seconds after the start of the first reclosure, reset at 9.46 seconds, restarted at 15.58 seconds and timed out at 23.58 seconds after the first reclosure. The high speed frequency record shows a pronounced transient at 23.58 seconds, and the high speed measurement of the Tarong-Braemar line flow shows a large change at that time. These support the assessment that this load was shed at that time.

## 4 UNDER-FREQUENCY LOAD SHEDDING THAT DID NOT OCCUR

The following load shedding did not occur as expected.

### 4.1 Load in South Australia (49.0 Hz)

This load has an under-frequency relay set at 49.0 Hz, but ElectraNet SA has advised that the loading was 0 MW at the time. Note that this is not provided as a frequency control ancillary service.

NEMMCO has no information that would suggest that the load shedding facility would not have operated as designed if the load had been in operation at the time.

### 4.2 Load in South Australia (48.95 Hz)

This is a load with under-frequency load shedding facilities set to operate at 48.95 Hz, which was not shed even though the frequency fell below the setting. It would normally have a level of about 30 MW. ETSA Utilities has advised that they are investigating the failure to trip.

### 4.3 Load in Queensland (48.95 Hz)

This load has under-frequency load shedding facilities set to operate at 48.95 Hz, which was not shed even though the frequency fell below the setting. The amount of load that can be shed in this block is 6 MW. NEMMCO's EMS records for the station show that the load actually increased by 7.5 MW. Powerlink has advised that a relay has been found to be faulty and replaced, and that the rise in load was probably due to tripping of embedded generation.

### 4.4 Load in Queensland (48.95 Hz)

This is a load with under-frequency load shedding facilities set to operate at 48.95 Hz, which was not shed even though the frequency fell below the setting. NEMMCO's EMS records show that its loading at the time was about 380 MW. Powerlink Queensland has advised that the failure to shed was due to an equipment malfunction, which has now been rectified.

### 4.5 Load in Australian Capital Territory

ActewAGL have advised that there is no under-frequency load shedding equipment installed to operate in the ACT.

## 5 FREQUENCY CONTROL ANCILLARY SERVICES

Most of the raise frequency control ancillary services were being provided by generating units at the time of the loss of generation, and so are not included in this report.

The market loads that were enabled for the dispatch interval ending 21:45 hrs to provide raise frequency control ancillary services by reducing the load are shown in Table 3.

**Table 3 Frequency control ancillary services provided by loads**

| Load | Fast raise service | Slow raise service | Delayed raise service |
|---|---|---|---|
| APD02 | 9 MW | | |
| PTH01 | | 5 MW | 5 MW |

The first load (APD02) did reduce its loading initially and the second load (PTH01) tripped as part of the under-frequency load shedding. A full assessment of frequency control ancillary service delivery will be included in the final report.

A number of hydro electric power stations with pumping capability are registered to provide frequency control ancillary services, but none were pumping at the time.

## 6 OTHER LOAD LOSS

TransGrid reported to NEMMCO that in addition to the under-frequency load shedding an estimated 340 MW of load in NSW was disconnected. This was due to a combination of customer interruptions due to the voltage disturbances and power station auxiliary load. NEMMCO has assessed from its EMS data that a total of 804 MW of load was lost in NSW, of which 462 MW can be accounted for by the under-frequency load shedding described above. This leaves 342 MW, consistent with TransGrid's estimation.

About 30 seconds after the first reclosure, a customer in Victoria reduced its load by about 50 MW. VicPower Trading is investigating.

## 7 LOAD RESTORATION

After stabilisation of the power system frequency to the normal operating frequency band (49.85 to 50.15 Hz) at about 21:47 hrs, NEMMCO commenced the process of load restoration. In accordance with operating procedures, this is achieved by NEMMCO assessing the power system's readiness to accept additional load, and granting permission to proceed to the Transmission Network Service Providers to restore specific amounts of load in their region. In the case of retail customer load, the Transmission Network Service Provider usually needs to request restoration by the relevant Distribution Network Service Provider.

At 21:56 hrs NEMMCO gave permission to proceed to ElectraNet SA to restore up to 50 MW of load, which was sufficient to cover all shed load in South Australia. Concerned about high voltage levels in parts of Queensland, NEMMCO gave Powerlink permission to proceed at 22:02 hrs for 50 MW of load to be restored, with the prospect of more when that was done.

In the mean time, permission to proceed was given to TransGrid to restore the two smaller loads in NSW, which are "sensitive loads" as defined in the National Electricity Code. At 22:04 hrs, permission to proceed was given to SPI PowerNet to restore two loads in Victoria, but withheld permission to restore a larger load in Victoria until restoration of the similar load in NSW, which is a "sensitive load".

Restoration in Queensland continued at 22:05 hrs with instruction to restore 50 MW of load. Instructions were given to restore a further 100 MW at 22:28 hrs when the initial 50 MW had been restored. At 22:35 hrs instruction was given to restore all remaining load in Queensland at a rate of 100 MW per 5 minutes. By 22:20 hrs all load in NSW, Victoria and South Australia was restored and by 23:00 hrs all load was restored in Queensland except for 5 MW with a technical problem.

No information is currently available about the restoration by customers of their load loss in NSW mentioned in section 6 above.

## 8 SYSTEM PERFORMANCE ASSESSMENT

The load shedding facilities generally performed according to design and, in conjunction with frequency control ancillary services, stabilised power system frequency within the limits and times required by the frequency operating standards.

Because of the quantity of under-frequency load shedding available under the National Electricity Code, the failure of three load blocks to shed did not adversely affect power system security.

Based on the information available, the amount of energy not supplied is estimated to be 1089 MWh. This is about 0.0006% of the expected total National Electricity Market energy delivery for the 2004/2005 financial year.

As can be expected, the major loss of generation in New South Wales caused increased flows from adjoining regions. The flow on the Queensland - New South Wales Interconnector increased by about 950 MW to a level of around 1200 MW to New South Wales. Similarly, the flow on the Victoria - New South Wales Interconnector increased by more than 900 MW to a level of around 850 MW to New South Wales before reducing as a result of Snowy generation. The power system security aspects will be fully considered in the final incident report.

The under-frequency load shedding outcome of this event was not balanced between the regions. Queensland and Victoria provided more load shedding than the other regions. Although the sharing of load shedding between regions was a factor in the design of the frequency settings for Queensland in 2001 and for Victoria in 2003, it is not possible to achieve equal sharing until load shedding is reviewed in all regions jointly. Equal sharing is not likely to be possible for all contingencies even after such a review.

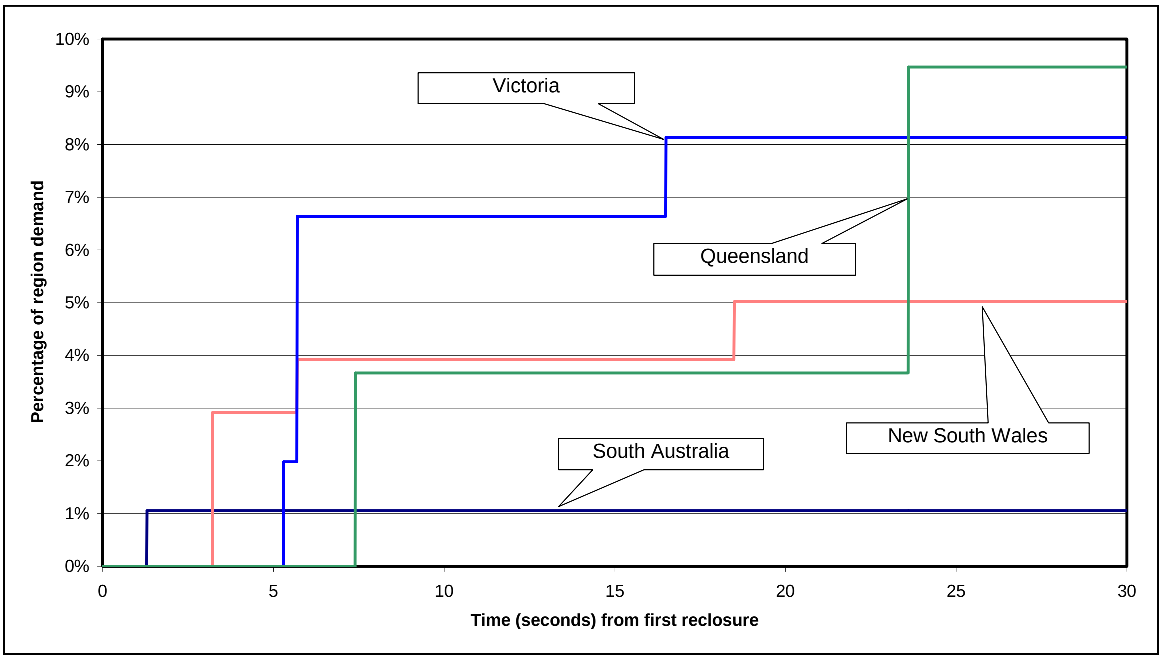
The amounts of under-frequency load shedding expressed as a percentage of each region's demand at 21:40 hrs on 13 Aug 2004 are set out in Table 4 below.

**Table 4 Load shedding distribution**

| Region | Demand (MW) | Load shed (MW) | As % of demand |
|---|---|---|---|
| New South Wales | 9208 | 462 | 5.0 |
| Queensland | 5726 | 542 | 9.5 |
| Snowy | 28 | 0 | 0 |
| South Australia | 1669 | 18 | 1.1 |
| Victoria | 5998 | 488 | 8.1 |
| NEM overall | 22629 | 1535 | 6.8 |

The progression of the load shedding during the disturbance expressed in percent of region demand is shown in Figure 2.

**Figure 2 Progression of load shedding**



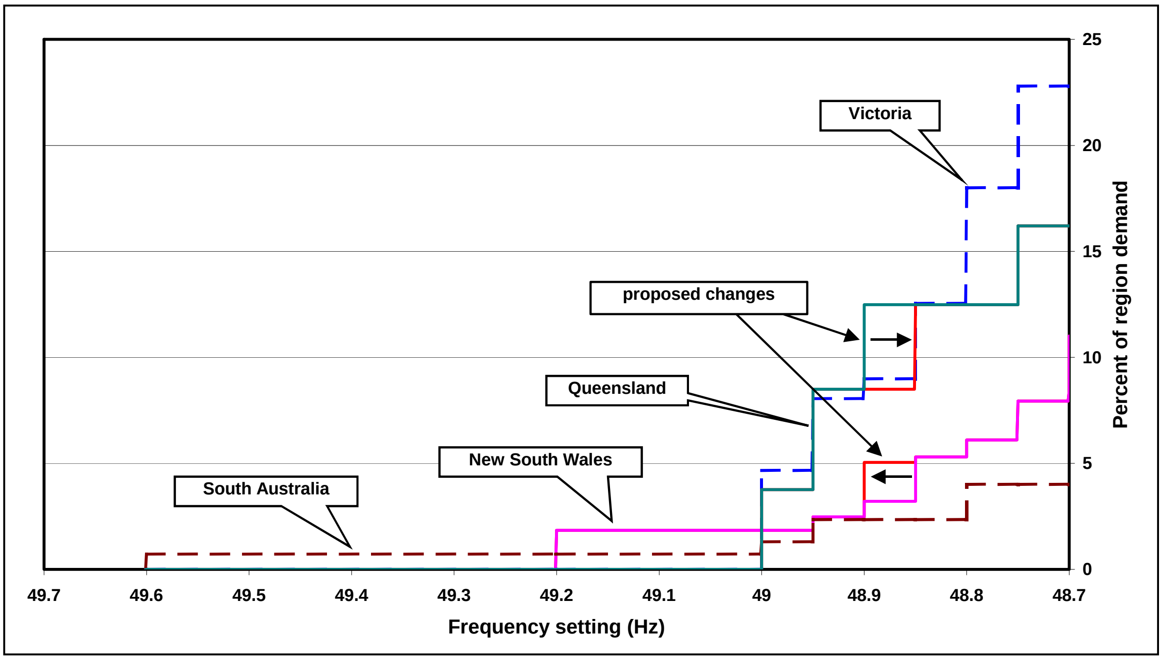

This assessment shows that Queensland provided more load shedding than would be expected by equitable sharing. A contributing factor appears to be the relatively large size of the Queensland under-frequency load shedding blocks as a percentage of region demand.

NEMMCO has carried out preliminary simulations to assess what might have happened if the under-frequency load shedding operation had been different. These preliminary assessments make assumptions about generation and frequency control ancillary service delivery and will be reviewed for the final report. It is clear from simulations that small changes in loads and settings could significantly change the balance of sharing between jurisdictions.

A full review of under-frequency load shedding across all regions is likely to take some time, and it is recommended that an interim minor adjustment be made to some under-frequency load shedding settings to address the most obvious imbalance. Figure 3 shows the accumulated load shedding amounts as a percentage of region historical maximum demand, plotted against frequency setting down to 48.7 Hz. In Victoria, new under-frequency load shedding facilities were installed at the end of September 2004, and the new settings have been used in this assessment for future conditions. Under-frequency load shedding blocks with time delays of 25 seconds or more (totalling approximately 800 MW in Victoria and Queensland) have been excluded because these are far less likely to trip.

Figure 3 shows that the imbalance between regions is quite significant. NEMMCO notes that the Queensland under-frequency load shedding block at 48.90 Hz extends beyond the others, and New South Wales and South Australia contribute less in proportion to their size. NEMMCO has therefore determined that the frequency settings of the Queensland block and a load block of similar size in New South Wales be exchanged as shown in Figure 3, as an interim improvement to the load shedding settings.

**Figure 3 Balance of load shedding**




## 9 PRELIMINARY RECOMMENDATIONS

This preliminary investigation has found that, the load shedding largely operated as designed, and frequency was restored in accordance with the frequency operating standards, however, the sharing of shedding between regions was not well balanced for this particular event.

The principal recommendation is that the under-frequency load shedding arrangements across the National Electricity Market should be reviewed. In this regard, NEMMCO has already commenced discussions with the Jurisdictional Coordinators to establish the principles to be applied to the review, including a basis for sharing of load shedding and restoration across the jurisdictions. NEMMCO has decided to make an interim change to one under-frequency load shedding block in Queensland and one in NSW in response to the imbalance revealed by this disturbance.

The following matters concerning or arising from load shedding also need further investigation for inclusion in the final report:

(a) The reasons why some under-frequency load shedding facilities did not operate as expected.

(b) The reason for the unexpected load reduction at a major load in Victoria.

(c) The adequacy of measurement facilities for assessing the performance of under-frequency load shedding.

(d) The arrangements for under-frequency load shedding in the Australian Capital Territory.

(e) The power system security aspects of the high interconnector flows.

(f) What other non-scheduled generating units also tripped during the disturbance.