NEMMCO

National Electricity Market Management Company Limited
ABN 94 072 010 327

Market Event Report 22 October 2007

Prepared by: Market Operations Performance

1. Introduction

This report has been prepared to review the reasons that led to high energy prices in the New South Wales, South Australia, Victorian and Tasmanian regions on the morning of Monday, 22 October 2007. During the same period, FCAS prices in all regions also increased above typical values. The increase in price resulted from the operation of an overly-conservative constraint.

The supply/demand conditions during the period in question were as follows:

- Constrained operation of the Terranora and QNI interconnectors by up to 500MW of flow into NSW during the planned outage of the Armidale to Coffs Harbour (87) 330kV transmission line;
- Constrained operation of the Hunter Valley generation in NSW by up to approximately 1,400MW due to the operation of an overly conservative constraint equation;
- Approximately 3,000MW of NSW generation was offline or unavailable; and
- The NSW system demand was approximately 10,000MW.

This led to the following market outcome:

- Violation of a system normal constraint equation, which was overly-conservative under the prior outage condition, from dispatch interval (DI) 08:05 to DI 09:55;
- Triggering of an automatic over-constrained dispatch (OCD) run at DI 09:40; and
- A DI 09:40 price of $9,700 and a 10:00am spot price of $7,858.07 for NSW.

Power system security was maintained during the period when the system normal constraint equation violated. This constraint equation was removed at 9:55am and a modified constraint equation invoked in time for DI 10:15 on the same day to account more appropriately for the outage of the Armidale to Coffs Harbour line.

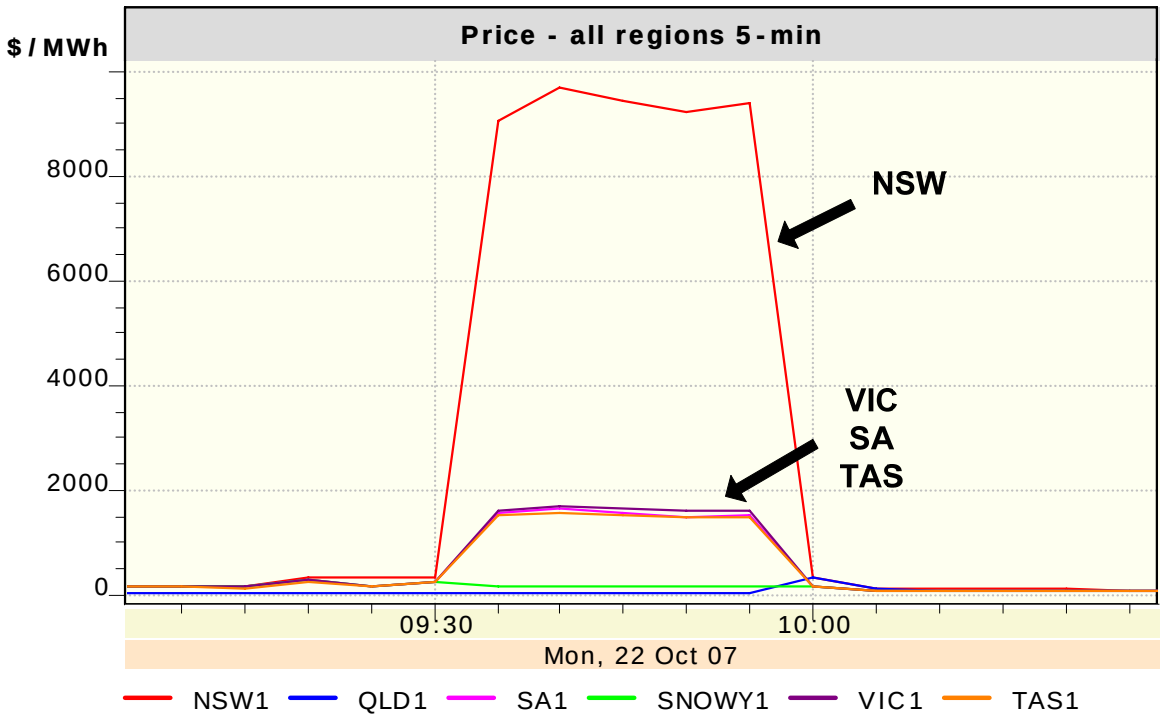
This report examines this incident in detail, declares a scheduling error and provides recommendations to:

- review the constraint equation formulation policy in conditions where a controlled variable has a very small influence on the managed flow; and
- develop procedures to determine if and under what conditions binding constraint equations may be removed.

2. Energy pricing outcomes

The following figure shows the dispatch interval (DI) prices for the relevant period.

Figure 1 – Dispatch Energy Prices for all regions in NEM

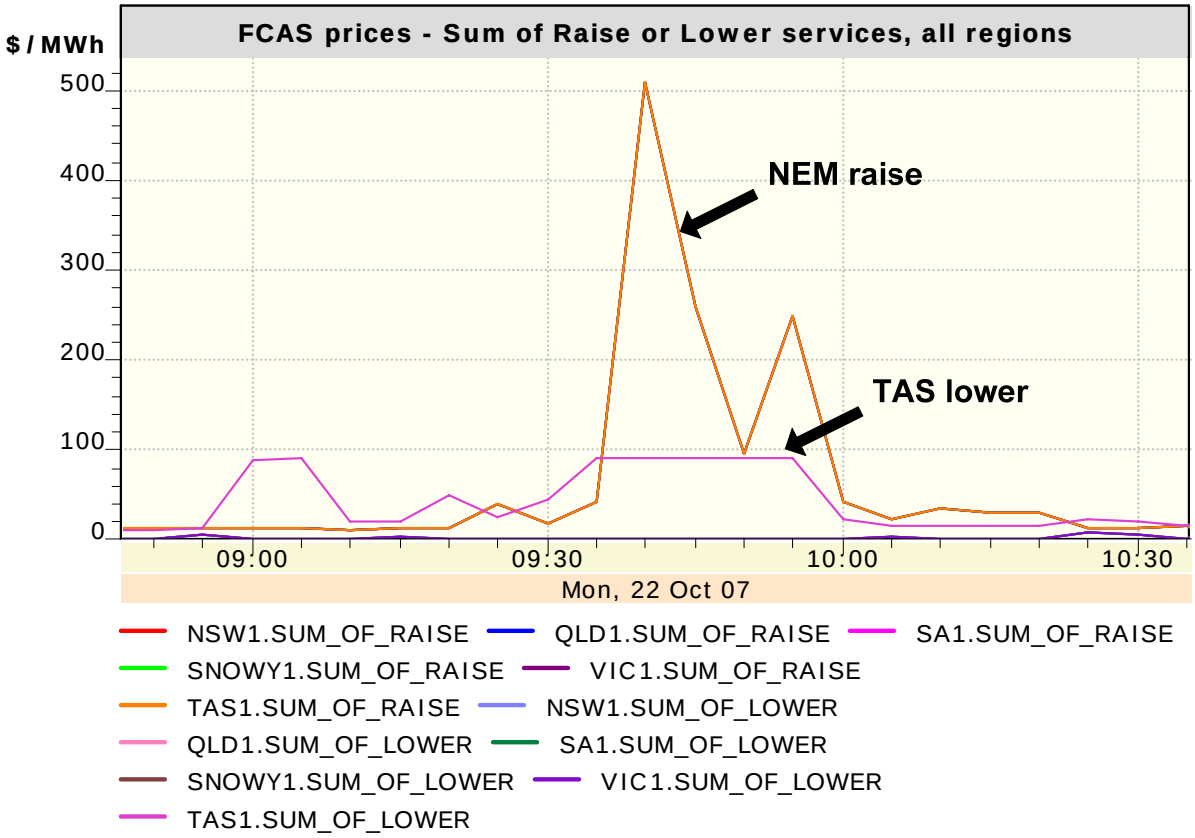


Energy prices in New South Wales, Victoria, South Australia and Tasmania increased on the morning of Monday, 22 October 2007. The trading intervals where the energy prices were above $300/MWh are highlighted in Table 1.

Table 1 – Trading Interval Energy Prices

Trading Interval Price Table ($/MWh)						
	Region					
Trading Interval	NSW1	QLD1	SA1	SNOWY1	TAS1	VIC1
9:30	255.03	33.12	189.36	187.14	179.02	191.79
10:00	7,858.07	81.94	1,323.04	150.00	1,284.41	1,389.09
10:30	89.73	83.32	75.92	81.91	71.67	78.48

Figure 2 – FCAS prices for all regions in NEM

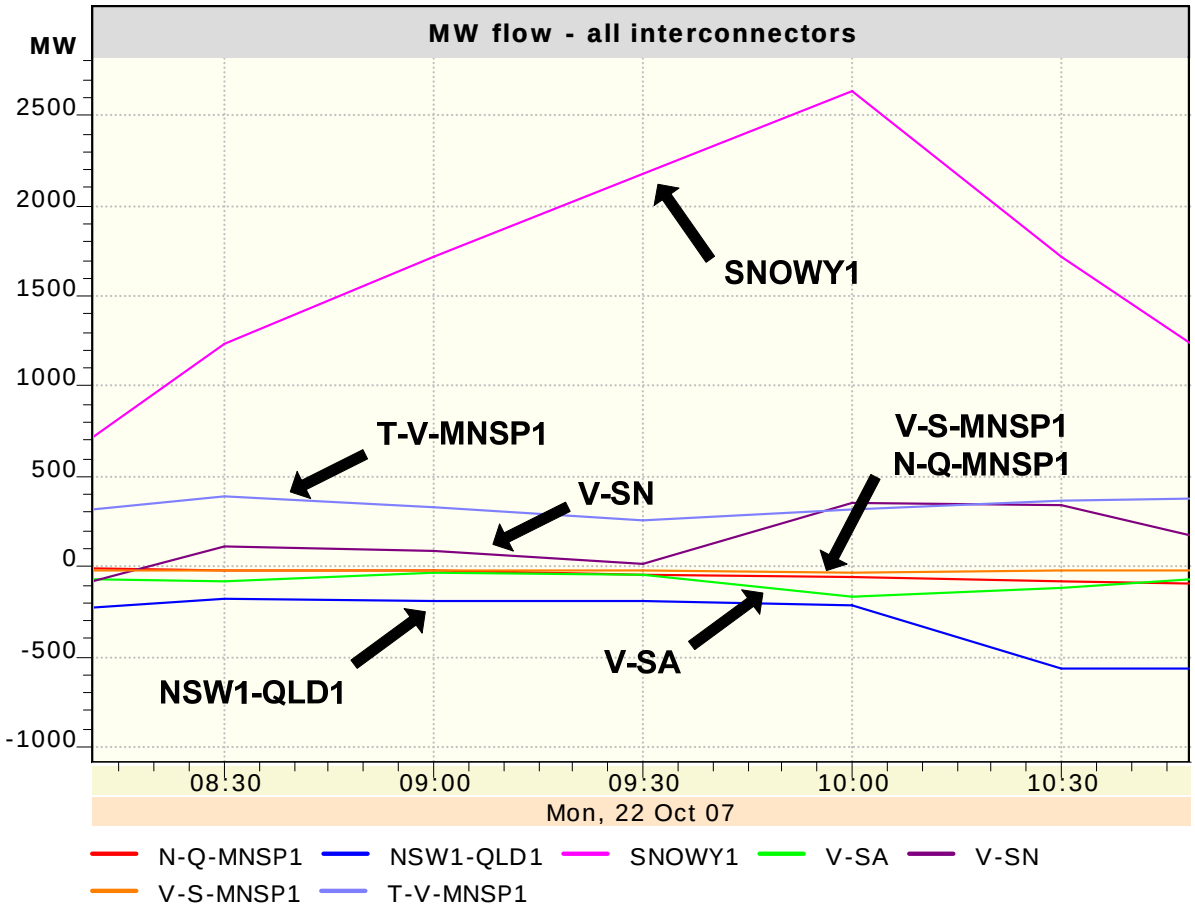


The raise FCAS prices in all regions increased above typical values on 22 October 2007, as shown in Figure 2.

3. Interconnectors

Figure 3 shows the target flows for all interconnectors in the NEM for the relevant periods.

Figure 3 – Target flows for all Interconnectors in NEM



Flows into the New South Wales region on the Snowy1 interconnector increased significantly between DI 08:00 and DI 10:00 while the transfer capability on the Terranora and QNI interconnectors reduced. Figures 4 and 5 show the target flow and limits for the Terranora and QNI interconnectors, respectively.

Figure 4 – Target flows and limits for Terranora Interconnector

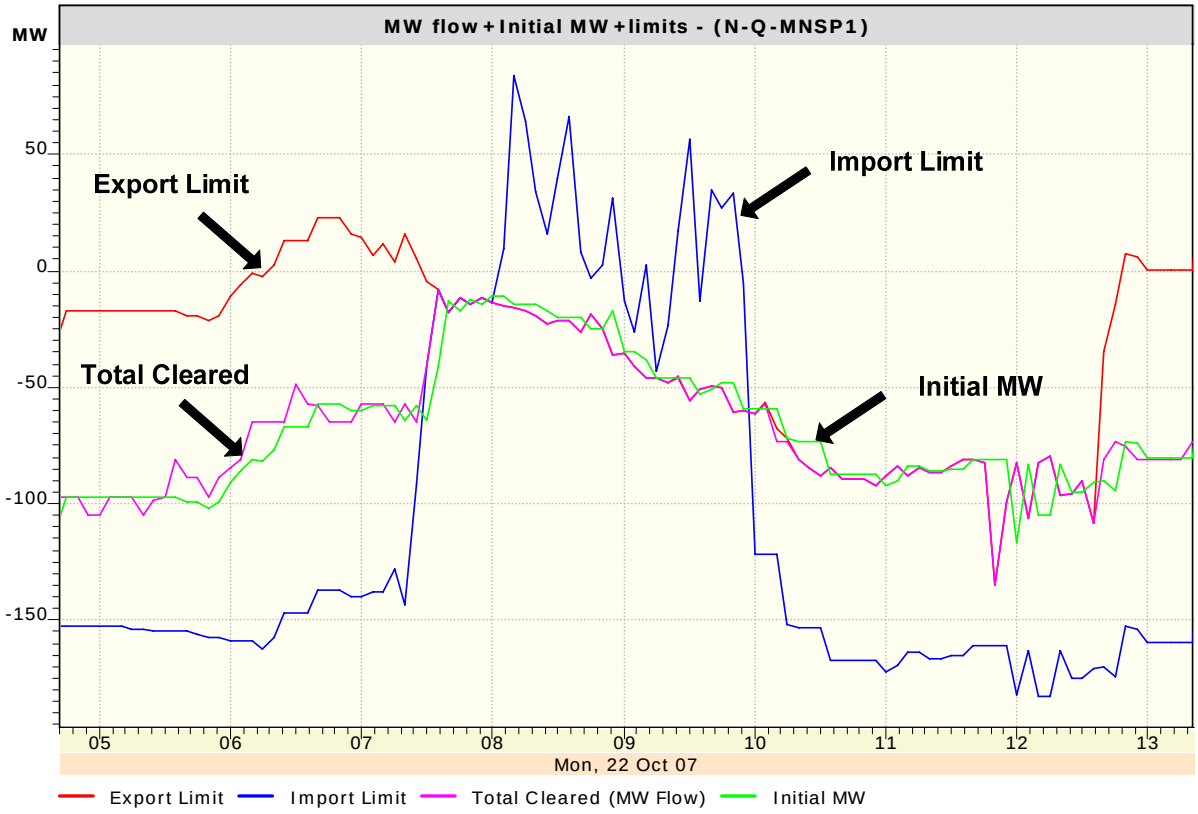
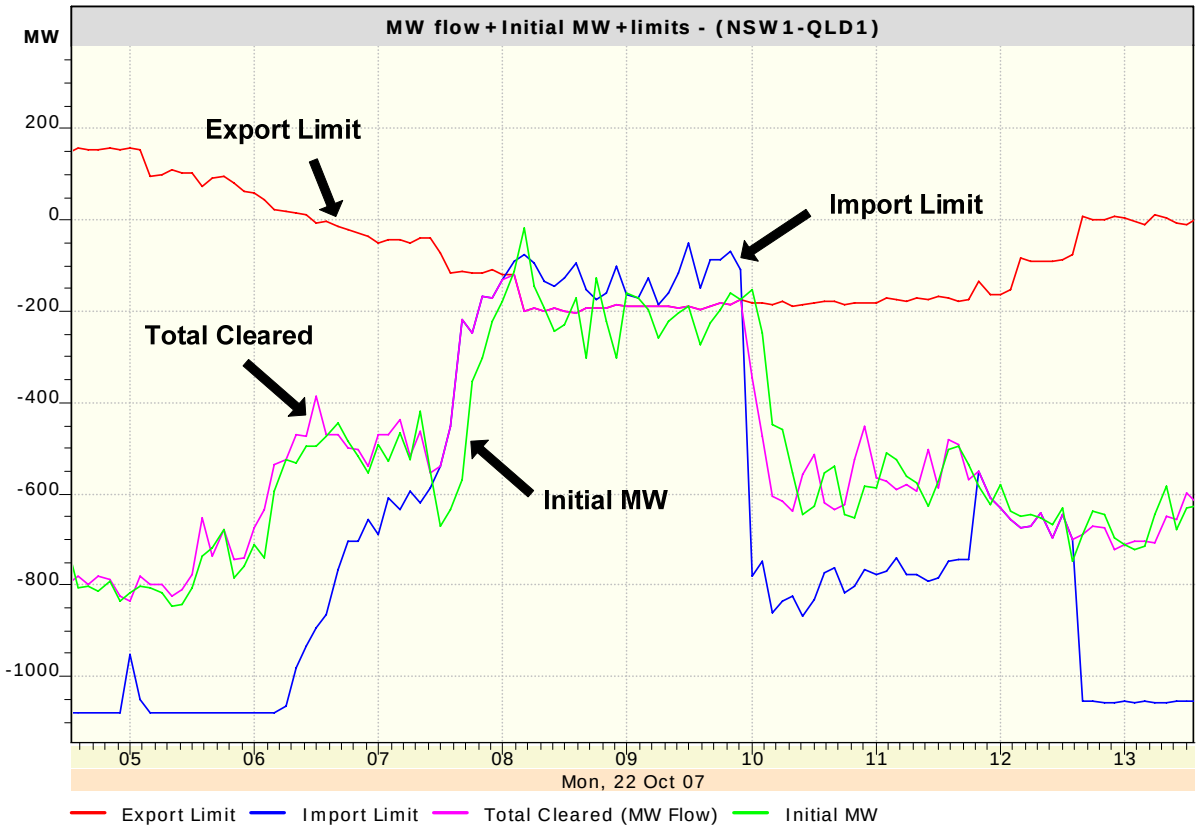


Figure 5 – Target flows and limits for QNI Interconnector



The constraint equation (N>>N-NIL_DF_1) that sets the import limits of both Terranora and QNI interconnectors started binding at DI 7:30 and violated between DI 08:05 and DI 09:55, as discussed in section 4.

During the same period, constraint equation (N^Q_NIL_B) was setting the export limits of the QNI interconnectors. This equation drives increased flow in the Queensland to New South Wales direction in order to avoid voltage collapse on loss of the largest Queensland generator.

The export limit for the Terranora interconnector was set by one of the two constraint equations: (N^Q_NIL_B) or (N>N-ARCH_87_TE_C2). The latter constraint equation manages the outage of the Armidale to Coffs Harbour (87) 330kV line. It avoids overloading of the Armidale to Coffs Harbour (96C) line on trip of the Armidale to Koolkhan (966) line.

As can be seen from Figures 4 and 5 the combined import limit on QNI and Terranora was reduced by up to 1,000MW with the actual flow into NSW between 07:45am and 10:00am constrained by 400-500MW. When the overly conservative constraint equation (N>>N-NIL_DF_1) was removed, the actual flow to NSW increased by about 400MW.

As outlined in section 4.1 NSW Hunter Valley generation was constrained off by up to approximately 1,400MW. This limitation, together with:

- limited available capacity on the Queensland interconnectors;
- approximately 3,000MW of NSW generation being offline or unavailable; and
- a 09:40am NSW system demand of 10,034MW,

resulted in a NSW DI 09:40 price of $9,700/MWh.

4. Constraint Equation N>>N-NIL_DF_1

A system normal (ie designed to operate in normal conditions with all network elements in service) constraint equation N>>N-NIL_DF_1 started binding from DI 7:30 and violated between DI 08:05 to DI 09:55 during the planned outage of the Armidale to Coffs Harbour (87) 330kV transmission line. Real-time contingency analysis indicated (and later off-line review confirmed) that power system security was not violated during that period. Section 4.1 discusses the constraint equation's operation, which led to generation in the Hunter Valley of NSW being constrained off. Details of the coefficients of the constraint equation and its formulation are attached in Appendix 2.

4.1 System normal constraint being overly conservative

The constraint equation N>>N-NIL_DF_1 operates to limit flows towards NSW on the Terranora and QNI interconnectors and constrain off generators at Bayswater, Liddell and Redbank in the Hunter Valley, New South Wales. It is designed to optimally set these variables to avoid overloading of the Armidale to Kempsey (965) line following the trip of the Coffs Harbour to Nambucca (9W3) line with the Armidale to Coffs Harbour (87) line in service.

NEMMCO's policy is to invoke outage constraint equation sets "on top" of (ie in addition to) the system normal set of constraint equations. This policy assumes that the technical envelope for an outage is more restrictive than the system normal envelope, and avoids the risks of identifying, concurrently revoking, and ultimately re-invoking the relevant system normal constraint equations. Under the 87 line prior outage condition, this system normal constraint equation was found to be unnecessarily restrictive on the controlled variables since the coefficients were not appropriate for the actual power system configuration with 87 line out of service.

Up to approximately 1400MW of generation capacity in the Hunter Valley was constrained off and supply from Queensland to New South Wales was restricted due to the planned outages. This restriction on Hunter Valley generation and an increase in demand required energy from other NSW Generators, which was offered at the higher priced bands, to be dispatched. This resulted in an increase in energy and FCAS prices in several regions.

Power system security was monitored by NEMMCO's Real Time Contingency Analysis (**RTCA**) application throughout the incident and no violations of satisfactory operating limits were identified even if any single contingency had occurred.

The overly conservative constraint equation was removed at 9:55am and a modified equation that was robust against the outage of the Armidale to Coffs Harbour line was tested and invoked in time for DI 10:15. The revised constraint equation was designed to be automatically relaxed so that it cannot bind when the 87 line is out of service.

NEMMCO has reviewed its management of the constraint equation replacement that occurred during this event. The constraint equation was identified as having an impact on market dispatch when it began to violate at around 08:00 hrs, and the issue was referred to off-line support staff. The overly conservative constraint equation was removed just prior to 09:55am for DI 10:00. NEMMCO has formed the view that although the overly conservative operation of the system normal constraint equation could not have been reasonably foreseen at the time it was constructed or when the outage was approved, NEMMCO staff could have acted more quickly to remove the overly conservative constraint equation to address the dispatch issue without compromising power system security under the circumstances of the day.

The ability to remove overly conservative constraint equations will vary with circumstances. NEMMCO should develop procedures to identify overly conservative constraint equations and determine if they may be removed without replacement by an alternative equation.

It would have been reasonable to expect that this overly conservative constraint equation could have been removed while still preserving power system security by 09:15 hrs (or about one hour from when the off-line support staff became involved), ie from DI 09:20, rather than leave the overly conservative constraint equation in place until DI 10:00. The new constraint equation had been developed, tested and implemented in time for DI 10:15.

4.2 Constraint equation formulation

The constraint equation N>>N-NIL_DF_1 operates such that in order to reduce the post-contingent flow across the managed line (Armidale to Kempsey 132kV) by 1MW, the QNI interconnector flow must change by 33MW, or the Hunter Valley Generators have to reduce by approximately 245MW. During the same period, the QNI and Terranora interconnector flow were also subject to other binding constraint equations, so that these variables were effectively unable to provide assistance in managing the flow on the 965 line. Therefore, a small change in local demand was able to exert a large impact on the dispatch targets of the constrained generators.

NEMMCO's constraint formulation policy[1] sets limits on the ratio between coefficients of terms on the LHS of constraint equations and requires that scaling factors are applied to the RHS so that the highest coefficient on the LHS is equal to unity. However there is no limit set in the policy for the scaling factor or the leverage that can occur in feedback type constraints due to the ratio of the scaling factor to the LHS coefficient.

[1] Network and FCAS Constraint Formulation Policy at http://nemmco.com.au/dispatchandpricing/170-0040.pdf

NEMMCO reviewed the constraint equation development procedures that led to the formation of the system normal constraint equation N>>N-NIL_DF_1 in such a way that it would operate conservatively when line 87 was out of service. That review concluded that it was not reasonable to expect an assessment of the impact of this outage should be considered, due to the complexity of the transmission network topology and the relatively large number of candidate outages that would need to be assessed for impact.

5. Conclusions and Recommendations

The market and power system conditions during the high energy and FCAS prices in several regions on 22 October 2007 were discussed in this report. A major factor contributing to the market outcomes was the operation of a system normal constraint equation that unnecessarily constrained off up to 1,400MW of NSW generation during the prior outage of the Armidale to Coffs Harbour (87) 330kV transmission line. The constraint equation was modified and invoked from DI 10:15 on the same day to take account of the prior outage.

Power system security was maintained throughout the event.

In response to the issues discussed in this report, it is recommended that:

- NEMMCO review its constraint equation formulation policy regarding the use of control variables in constraint equations with very small influence on the managed flow; and
- NEMMCO develop procedures to clarify the process for the safe removal of overly conservative constraint equations.

The operation of constraint equation N>>N-NIL_DF_1 was found to be overly conservative for the power system operating conditions prevailing during the outage of the 330kV Coffs-Harbour (87) line on 22 October 2007. The constraint equation bound and was violated at levels that were inconsistent with the maintenance of power system security, causing up to 1,400MW of NSW generation to be constrained off. NEMMCO has formed the view that it would be reasonable to expect that alternative remedial action should have been taken by 09:15 hrs in this event, rather than allowing the operation of the overly conservative constraint equation to continue until 09:55 hrs. Accordingly NEMMCO declares[2] that it failed to follow the central dispatch process and, hence, a scheduling error occurred on 22 October 2007 for the dispatch intervals ending 09:20 through to 10:00 am, noting that it took some time after 10:00am for the dispatch of Hunter Valley generation to return to optimal steady state levels.

[2] See Rule 3.8.24(a)(2)

Appendix 1: Glossary of Abbreviations

Abbreviation	Meaning
FCAS	Frequency Control Ancillary Services
R6	Raise 6 second FCAS service
R60	Raise 60 second FCAS service
R5	Raise 5 minute FCAS service
RReg	Raise regulation FCAS service
L6	Lower 6 second FCAS service
L60	Lower 60 second FCAS service
L5	Lower 5 minute FCAS service
LReg	Lower regulation FCAS service
LHS	Left hand (controllable variable) Side of a constraint equation
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine
NEMMCO	National Electricity Market Management Company
OCD	Over Constrained Dispatch
RHS	Right Hand Side
RRP	Regional Reference Price
RTCA	Real Time Contingency Analysis – application that examines the condition of the power system after all credible single contingencies
DI	Dispatch Interval
TI	Trading Interval

Appendix 2: Constraint Equation N>>N-NIL_DF_1

Constraint type: LHS<=RHS
Effective date: 18/12/2006
Version No: 1
Weight: 20
Constraint active in: Dispatch, Predispatch, ST PASA, MT PASA
5 Min Predispatch RHS:
Active in PASA for: LRC & LOR

Constraint description: Out= Nil, avoid Armidale->Kempsey(965) OL(15m rat) on Coffs_Harbour-Nambucca(9W3) trip, both Raleigh and Sawtell loads supplied ex Coffs_H, TG_spec
Impact: NSW - Qld (QNI) Interconnector + Terranora
Source: Transgrid
Limit type: Thermal
Reason: Trip of Coffs Harbour to Nambucca (9W3) line
Modifications: Replace Armidale volts calc with new Generic Equation
Additional Notes:

LHS=

0.11 x Unit 1 Bayswater PS
0.11 x Unit 2 Bayswater PS
0.11 x Unit 3 Bayswater PS
0.11 x Unit 4 Bayswater PS
0.116 x Unit 1 Liddell PS
0.116 x Unit 2 Liddell PS
0.116 x Unit 3 Liddell PS
0.116 x Unit 4 Liddell PS
0.164 x Unit 1 Redbank PS
- MW flow north on the Directlink DC Interconnector
-0.809 x MW flow north on the QNI AC Interconnector

RHS

Default RHS value= 1000

Dispatch RHS=
26.95 x ((0
+ NSW: 965 Armidale - Kempsey 132kV 15 min Rating)
x (0.56 x (*Generic Equation:* ARMIDALE_132VOLTS))
+ -2 {Adv_Bias}
+ 6 {Both_R&S_load_exCH}
+ 0.03 x (MW flow north on the Directlink DC Interconnector)
+ 0.03 x (*Generic Equation:* TERRANORA_LOAD)
+ -1 x (MW flow on 965 132kV line at Armidale, Line end switched MW)

+ -1 {Margin})
+ -0.809 x (MW flow north on the QNI AC Interconnector)
+ -1 x (MW flow north on the Directlink DC Interconnector)
+ 0.11 x (Unit 1 Bayswater PS)
+ 0.11 x (Unit 2 Bayswater PS)
+ 0.11 x (Unit 3 Bayswater PS)
+ 0.11 x (Unit 4 Bayswater PS)
+ 0.116 x (Unit 1 Liddell PS)
+ 0.116 x (Unit 2 Liddell PS)
+ 0.116 x (Unit 3 Liddell PS)
+ 0.116 x (Unit 4 Liddell PS)
+ 0.164 x (Unit 1 Redbank PS)

NB 26.95 is a scaling factor applied to both sides of the constraint equation so that the (absolute value of the) largest coefficient on the LHS (for DirectLink) is 1.0

Equation: ARMIDALE_132VOLTS (per unit)

Min(1.15, Max (0.85, 0.007576 x V))

Where V=Max (Voltage on the Armidale #3 132kV bus,
Voltage on the Armidale #1 132kV bus,
Voltage on the Armidale #5 132kV bus) in volts
ie maximum 132kV busbar voltage at Armidale in per unit terms with upper and lower limits set at 1.15 and 0.85 respectively.

Equation: TERRANORA_LOAD

0.018 x (0
+ Queensland region demand
+ -1 x (Northern Queensland Area)
+ -1 x (Central Queensland Area))
+ -5 {Offset}