Appendix D Historical congestion between Victoria, Snowy, and NSW regions

This Appendix assesses the historical frequency, type and location of congestion between the Snowy region and the regional reference nodes for Victoria and NSW in the three year period from financial year 2003/04 to 2005/06. Information on the locations of binding constraints will enable the Commission to understand:

1. The historic level of congestion at the proposed borders of the new regions;
2. The possible consequences of abolishing the existing Snowy region boundaries and replacing them with boundaries at other locations of the network; and
3. The limitations of using historical data on network congestion at particular points of the network to assess potential future congestion.

1.8 Summary

Examining the historical pattern of congestion in the period between 1 July 2003 to 9 May 2006 reveals:

1. Snowy-NSW interconnector:
   (a) The vast bulk of binding cut-set constraints that limit Snowy-NSW interconnector flows in both directions arise under system normal conditions.

   (b) Constraints on the Murray-Tumut cut-set are the most frequent limitation on the interconnector flow capacity under system normal conditions. There has been a large increase in the frequency of Murray-Tumut constraints binding between 2003/04 and 2005/06, which possibly reflect changes to Snowy Hydro's bidding incentives over this period of time.

   (c) Discretionary constraints are the second most frequent limitation on Snowy-NSW interconnector flows. However, there has been a significant reduction in the use of discretionary constraints over the three years.

   (d) Together, constraints north and south of Marulan are the third most frequent limitation on Snowy-NSW interconnector flows. However, these only tend to bind under outage conditions, possibly because generators south of the constraint (e.g. Snowy Hydro, Wallerawang, Mount Piper) adjust their output to maintain "headroom" on the cut-set constraints.

   (e) Constraints on the North Tumut cut-set (i.e. between Tumut and Canberra/Yass) rarely limit interconnector flows. This result is at odds with the Macquarie Generation proposal, which locates a regional boundary at this cut-set on the basis that it is a major "pinch point".

1. VIC-Snowy interconnector:

   (a) Around 80% of all binding cut-set constraints that limit VIC-Snowy interconnector flows in both directions arise under system normal conditions.

   (b) Stability constraints are the most frequent limitation on flows along the VIC-Snowy interconnector.

   (c) South Morang transformer constraints, Voltage constraints, and Murray-Tumut cut-set constraints were, respectively, three next most frequent limitations on interconnector flows over the three years.

   (d) Constraints between Dederang and South Morang very rarely represent the most limiting factor on interconnector flows. This result is at also odds with the Macquarie Generation proposal, which locates a regional boundary at this cut-set on the basis that it is a major "pinch point".

Information on the historical frequency and location of congestion between Victoria, Snowy and NSW should be used with caution because past congestion is not an indicator of future congestion, unless circumstances are unchanged. Because of this, forward looking modelling that accounts for changed circumstances and economic incentives is required to assess the potential economic efficiency impacts of potential changes in the location of region boundaries.

1.9 Historic data on the incidence of congestion between VIC and NSW, 2002/03 to 2005/06

NEMMCO provided the Commission with the following statistical data on four "directional interconnectors" — VIC-Snowy, Snowy-VIC, Snowy-NSW and NSW-Snowy:

- The frequency of binding constraints, by cut-set, by constraint type, by financial year, by season (summer, autumn, winter, spring), and time of day (peak, off-peak).

The data is extracted from NEMMCO's Market Management Systems (MMS) and covers the period between 1 July 2002 and 9 May 2006. NEMMCO have calculated the most binding constraint on each interconnector in each 5-minute dispatch interval, and then calculated the frequency of binding constraints across each financial year.

Before assessing this data, it is important to gain a clear understanding of:

- the various network elements that make up the interconnectors;
- how these elements can be grouped into geographic "cut-sets";
- the types of limits and constraints that affect cut-sets; and

- how different types of cut-set limits affect the overall transfer capacity of an interconnector.

The interconnection between the regional reference nodes of Victoria (Thomastown), Snowy (Murray), and NSW (Sydney West) comprises many individual transmission lines at voltages of 330kV (orange), 220kV (blue) and 132kV (red) — see Figure D.1. The backbone is the 330kV network, which also links with the 500kV networks (yellow) of Victoria and NSW. Associated with these lines are transformers, switching stations, and network support and control infrastructure.

Figure D.1 Transmission network elements – VIC-Snowy and Snowy-NSW Interconnectors

Data source: NEMMCO

For dispatch and pricing purposes, the Rules group these lines into two "notional interconnectors" (Table D.1), along which power flow is measured at the regional boundary. By convention, the direction of flow from VIC to NSW is assigned a positive sign and the reverse flow a negative sign. These flow conventions allow each interconnector to be divided into two individual "directional interconnectors"—one for each direction of power flow (see Table D.1).

Table D.1: Interconnectors & directional interconnectors, VIC to NSW

Notional Interconnector	Direction of flow on interconnector	Sign convention for flow direction	Directional interconnector
V-Snowy	VIC to Snowy	+	VIC-SNY
	Snowy to VIC	-	SNY-VIC
SNOWY1	Snowy to NSW	+	SNY-NSW
	NSW to Snowy	-	NSW-SNY

Each interconnector can also be divided into a series of "cut-sets" (or "flow path").

1.9.1 Cut-sets

A cut-set is group of transmission lines that limits power transfers from one area to another and whose removal from the network's topology (via switching or an outage) would split the network in two, one on each side of the cut-set.[239]

The maximum power that can be transferred across a cut-set is limited by thermal and stability constraints. The power transfer limitations applying to a cut-set mean that the cut-set is sometimes referred to as a "transmission pinch point".

The NEM's very long AC transmission network (over 4,000km), widely dispersed and unbalanced centres of generation and load, all contribute to stability constraints (rather than thermal constraints) often being the most significant limitation on power transfers across cut-sets.

Each notional interconnector in the NEM comprises the group of cut-sets affecting power flows between two regional reference nodes. Limits on each cut-set in the group limits the power transfer capability between two segments of the notional interconnector, and hence limit the transfers across the entire interconnector.

239 **Cut-set** (electricity) A set of branches of a network such that the cutting of all the branches of the set increases the number of separate parts of the network, but the cutting of all the branches except one does not.

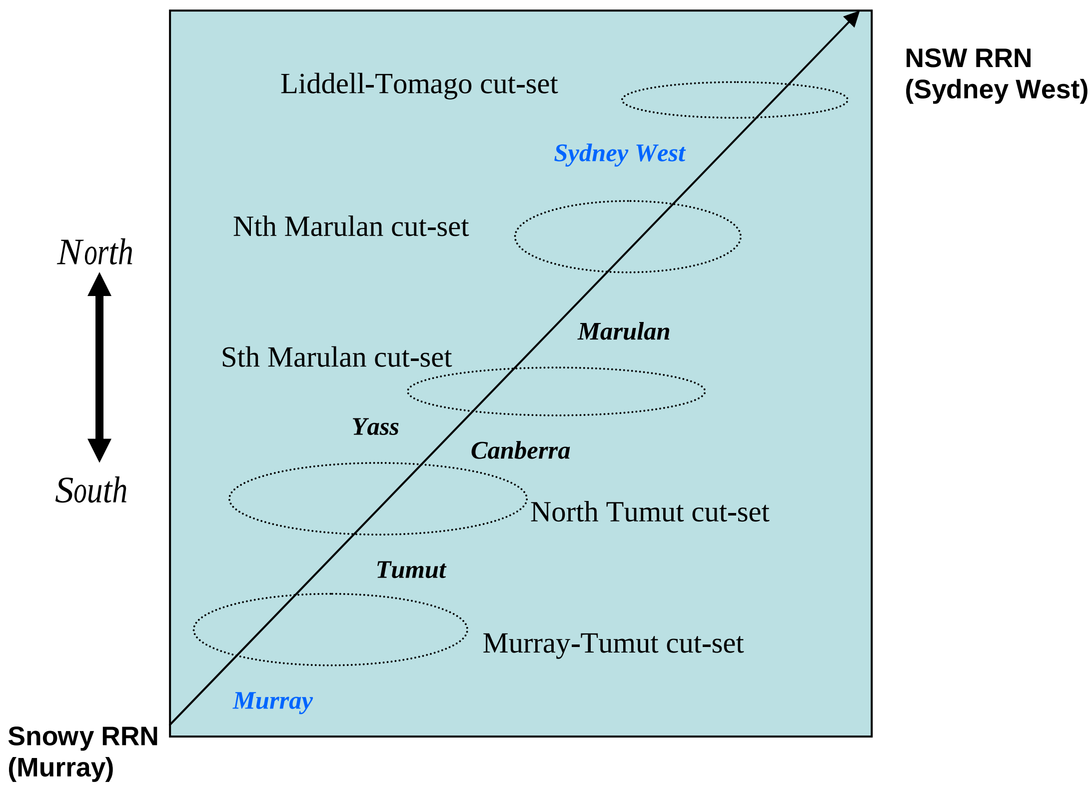
1.9.1.1 Snowy-NSW interconnector (Snowy1)

Figure D.2 is a simplified representation of in the Snowy-NSW interconnector, which comprises four cut-sets of lines between the Snowy RRN (Murray) and the NSW RRN (Sydney West). The box containing all the cut-sets comprises the notional interconnector, as does the single diagonal line running from the south-west corner of the box to the northeast corner. This single line is a simplification of the many lines that make up the cut-sets that together form the interconnector. Significant connection points used to define the cut-sets are shown next to the diagonal line, for example *Canberra* and *Marulan*.

Importantly, the Liddell-Tomago cut-set, which lies to the north of Sydney West, can also limit flows from Murray to Sydney West.

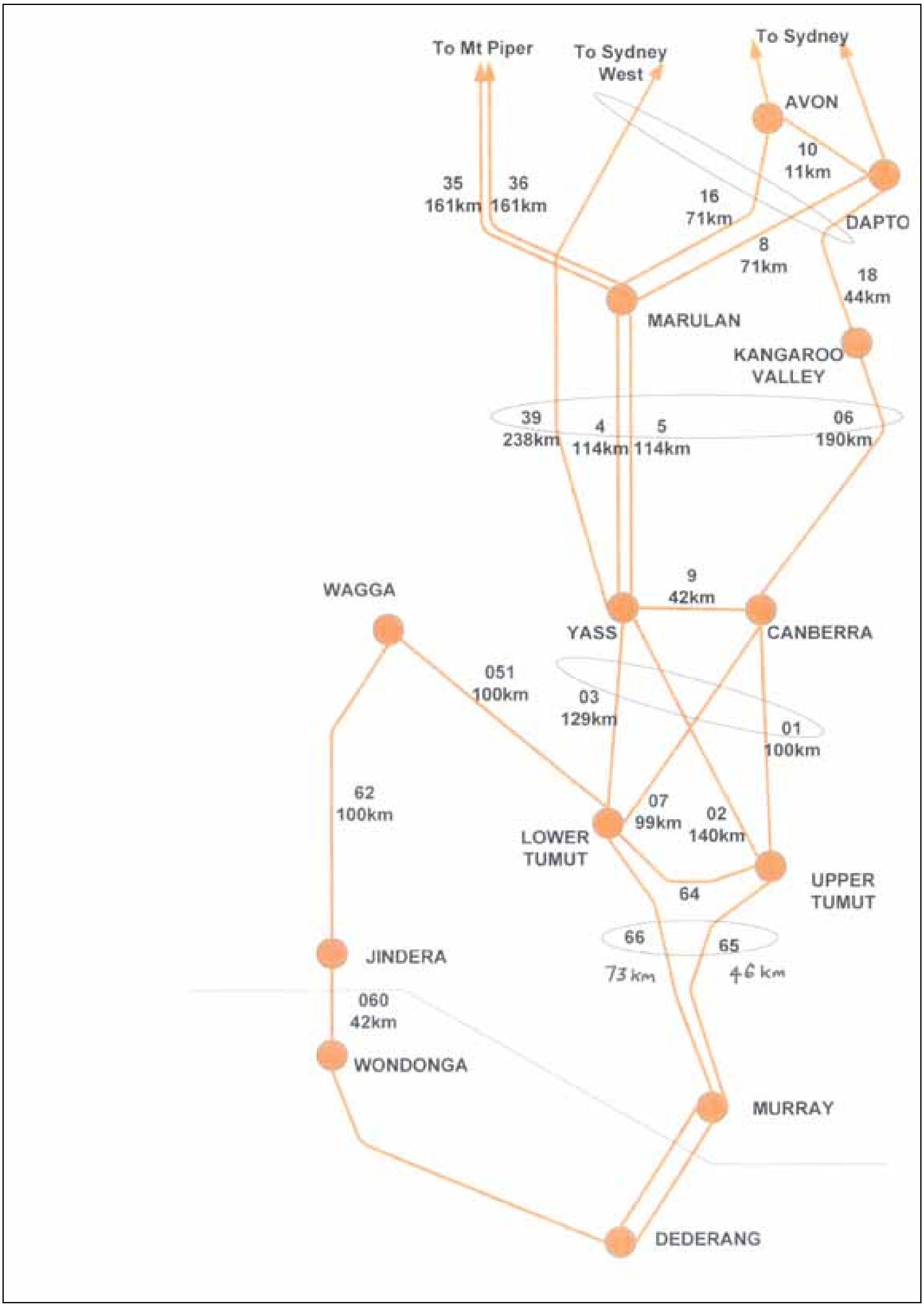
These five cut-sets closely correspond to those in the 17-zone ANTS model in NEMMCO's 2005 *Statement of Opportunities*.

Figure D.2 Simplified representation of Snowy-NSW notional interconnector



A more detailed picture of the transmission lines that form the four southern cut-sets on the Snowy-NSW interconnector is shown in Figure D.3 The lines are numbered and their length is shown. For example, in Figure D.3, the line from Murray to Upper Tumut is the "65 line", whose length is 46km. The length of a line affects its electrical impedance and degree to which voltage drops along the line as power flows from one end to the other. In general, the longer the line, the greater its impedance (i.e. losses) and voltage drop.

Figure D.3 Snowy-NSW interconnector – transmission lines and cut-sets, detail



Data source: TransGrid

TransGrid's 2006 Annual Planning Report (APR) states that limitations on the Snowy-NSW interconnector's transfer capability are affected by five factors:

1. thermal limits on lines in the South Marulan cut-set, which restrict the level of flows both north and south. At present, the limits predominantly restrict to southwards flows;[240]

2. thermal ratings of lines in the Murray-Tumut cut-set;[241]

3. transient stability limits that apply in the "event of a fault on a critical 330kV transmission line in southern NSW [i.e., the Wagga to Darlington Point line]";[242]

4. "thermal ratings of plant in southern NSW" around Wagga and between Wagga and Yass;[243]

5. voltage control and reactive power limitations around Canberra.[244]

NSW import capability along the Snowy-NSW interconnector is currently determined at different times by factors 1), 2), 4) and 5) above.

NSW export capability to the Snowy and VIC regions is currently determined at different times by factors 3), 1), 2) and 4) above.

1.9.1.2 VIC-Snowy Interconnector

Figure D.4 is a simplified representation of in the VIC-Snowy interconnector, whose transfer capability is limited by:

- two cut-sets of lines between South Morang (near the VIC RRN (Thomastown)) and the Snowy RRN (Murray) and the NSW RRN (Sydney West);

- three cut-sets to the north of Murray; and

- transformers located at South Morang and Dederang. The South Morang transformers convert La Trobe Valley's power from 220kV to 330kV, 500kV to 330kV. The three Dederang transformers alter voltages from 220kV to 330kV.

240 TransGrid, APR 2006, p. 60

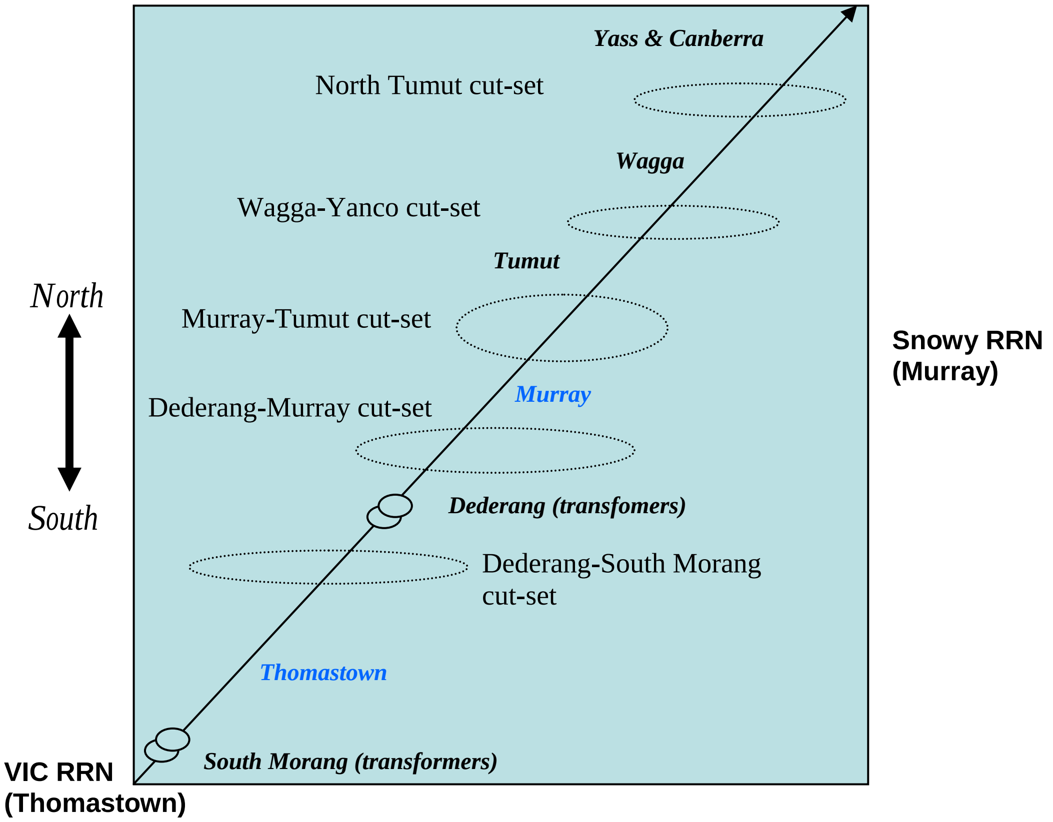
241 TransGrid, APR 2006, p. 78

242 TransGrid, APR 2006, p. 78, p.88

243 TransGrid, APR 2006, p. 78-80

244 TransGrid, APR 2006, p. 79

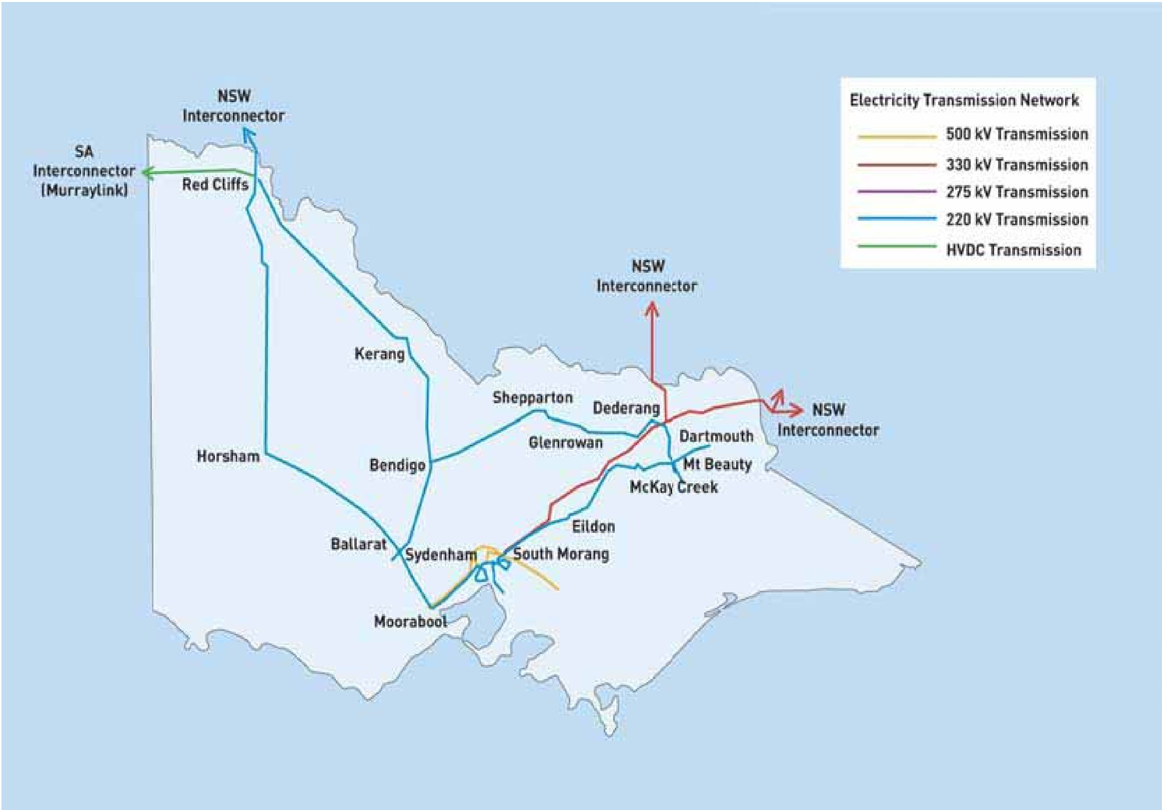
Figure D.4 Simplified representation of VIC-Snowy notional interconnector



As with the Snowy-NSW interconnector, the five cut-sets on the VIC-Snowy interconnector are similar to those in NEMMCO's 17-zone ANTS model.

Figure D.5 shows the 330kV, 220kV lines that make up the VIC-Snowy interconnector. The South Morang Terminal Station is the key point where power from the La Trobe Valley's 500kV and 220kV lines is injected into the VIC-Snowy interconnector.

Figure D.5 VIC-Snowy – main transmission elements



Data source: VenCorp 2006 APR (Electricity), p.61

VenCorp's 2006 APR states that:

Victorian import capability on the VIC-Snowy interconnector is determined by:[245]

1. thermal limits on the 330kV lines in the Dederang-Murray cut-set, which largely define the "system normal" upper import limit of 1,900MW;

2. overlapping voltage collapse and thermal constraints (on the Dederang transformers constraints and Eildon to Thomastown 220kV line) that apply in the event of an outage to one of the lines in the Dederang-South Morang cut-set;

3. thermal constraints on the three Dederang 330/220kV transformers. Under system normal conditions and no generation from Kiewa or Eildon, constraints on the Dederang transformers limit VIC imports from Snowy to around 1,200MW. Under system normal and more than 60% of Kiewa or Eildon generation dispatched, import capability of up to 1,900MW is possible. An outage of one of the Dederang transformers can reduce Snowy-VIC import capability to between 100MW and 1400, depending on Kiewa and Eildon generation;

245 VenCorp 2006, *Electricity Annual Planning Report 2006*, VenCorp, Melbourne, pp. 62–65

4. thermal constraints on the Eildon to Thomastown 200kV line when there is an outage of one of the 330kV lines in the Dederang-South Morang cut-set, can (in combination with other constraints) restrict Victorian imports from Snowy to around 1,200MW; and

5. thermal limits on the South Morang 220/330kv and 500/330kV transformers.

Victorian export capability on the VIC-Snowy interconnector is determined by:[246]

1. thermal limits on the 330kV lines in the Dederang-South Morang cut-set, which restrict exports to between 1,000MW and 1,150 MW when all other plant is in service;

2. In the event of an outage to one of 300kV lines in the Dederang-Murray cut-set, the VIC-Snowy export limit is reduced by around 130MW; and

3. thermal limits on the South Morang 220/330kv and 500/330kV transformers.

1.10 Analysis of Historic Pattern of Constraints — 2003/04 to 2005/06

In the period 2003/04 to 2005/06, according to NEMMCO data, binding constraints on five cut-sets affected flows on the SNYNSW interconnector. In the same period, binding constraints on six cut-sets affected flows on the VICSNY interconnector.

Table D.1 identifies three broad constraint types of constraints that restrict power flows along the cut-sets that comprise each interconnector. Stability and voltage constraints generally apply to the whole interconnector and are difficult to assign to a particular cut-set, so are a separately categorised.

Table D.2: Constraint types

Constraint types	Snowy-NSW Interconnector	VIC-Snowy Interconnector
Cut-set thermal limitations or contingency constraints for loss of lines in the cut-set	Liddell-Tim	Nth Tumut
	Nth Marulan	Yass-Control
	Sth Marulan	Wagga-Yanco
	Nth Tumut	Murray-Tumut
	Murray-Tumut	Ded-Murray
		Ded-Sth Morang
Transformer overloading or loss contingency constraints		Dederang Tx
		Sth Morang Tx
Other security constraints on interconnectors		Voltage
	Stability	Stability
	Discretionary	Discretionary

246 VenCorp 2006, *Electricity Annual Planning Report 2006*, VenCorp, Melbourne, pp. 62–65

The frequency and location of binding constraints differs depending on whether the flow is northwards or southwards along an interconnector.

1.10.1 Snowy-NSW interconnector

Table D.3 shows the frequency and location of binding constraints along the Snowy-NSW interconnector between 1 July 2003 and 9 May 2006, for flows both to and from the Snowy region. The data shows the number of 5-minute dispatch intervals in which a cut-set constraint was both binding and the most restrictive constraint on the entire interconnector. The data includes all times of the day (peak and off-peak), all four seasons (summer, autumn, winter, spring), and outage conditions (system normal, network outage).

It should be noted that on many occasions, multiple constraints are binding in a way that affects interconnector flows. By focussing on the most restrictive binding constraint in a dispatch interval, it is possible to characterise the location and type of constraint that is having the greatest influence in limiting flow along the interconnector. The more frequently a particular constraint sets the overall flow-limit of an interconnector, the greater its effect on dispatch outcomes.

Table D.3: Frequency of most binding constraints (No. dispatch intervals binding), Snowy-NSW interconnector (Snowy1), System Normal & Outage conditions, 1 July 2003 to 9 May 2006

Frequency for Snowy-NSW	Year			
Key	2003/04	2004/05	2005/06	Grand Total
Liddell-Tim			49	49
Nth Marulan			20	20
Sth Marulan		17	13	30
Nth Tumut	11	12	4	27
Murray-Tumut	91	416	1,190	1,697
Stability	11	28		39
Discretionary	24	39	8	71
Grand Total	137	512	1,284	1,933

Data source: NEMMCO

The following observations can be made about the data in Table D.3:

1. Constraints on the Murray-Tumut cut-set are the most frequent limitation on the interconnector flow capacity. There has been a large increase in the frequency of Murray-Tumut constraints binding between 2003/04 and 2005/06. These constraints bound for 91 dispatch intervals (or 7.6 hours) in 2003/04, rising to 1190 dispatch intervals (or 99 hours) in 2005/06;

2. Discretionary constraints are the second most frequent limitation on interconnector flows. However, there has been a significant reduction in the use of discretionary constraints over the three years;

3. Together, constraints north and south of Marulan are the third most frequent limitation on interconnector flows;

4. Constraints on the North Tumut cut-set (i.e. between Tumut and Canberra/Yass) rarely limit interconnector flows. This result is at odds with the Macquarie Generation proposal, which locates a regional boundary at this cut-set on the basis that it is a major “pinch point”; and

5. In 2005/06, Liddell-Tomago cut-set constraints were the third most frequent limiting factor on Snowy1 interconnector flows.

The increased level of congestion on the Murray-Tumut cut-set is likely to associated with a number of factors, including: i) increasing application of “fully optimised” constraint formulations by NEMMCO; ii) changes in Snowy Hydro’s contract position; and iii) implementation of the Tumut CSP/CSC Trial and its impacts on Snowy Hydro’s incentives and bidding behaviour.

Similarly, the reduction in the use of discretionary constraints could be linked to: i) different patterns of line outages over time; and/or ii) increased network control arising from the use of “fully optimised” constraint forms.

Table D.4 splits the data in Table D.3 into the frequency of binding constraints limiting:

- flows north from the Snowy region to the NSW region (Exports from Snowy);
- flows south from the NSW region to the Snowy region (Imports to Snowy).

This information enables further insights into constraints on the interconnector.

Table D.4: Frequency of most binding constraints by direction of flow (No. dispatch intervals binding), Snowy-NSW interconnector (Snowy1), System Normal & Outage conditions, 1 July 2003 to 9 May 2006

		Year			Grand Total
Key	Data	2003/04	2004/05	2005/06	
Liddell-Tom	Export (SN to NSW)			49	49
	Import (NSW to SN)			1	1
Nth Marulan	Export (SN to NSW)			20	20
	Import (NSW to SN)			0	0
Sth Marulan	Export (SN to NSW)		0	0	0
	Import (NSW to SN)		17	13	30
Nth Tumut	Export (SN to NSW)	1	12	4	17
	Import (NSW to SN)	10	0	0	10
Murray-Tumut	Export (SN to NSW)	14	293	788	1095
	Import (NSW to SN)	77	123	402	602
Stability	Export (SN to NSW)	0	0		0
	Import (NSW to SN)	11	28		39
Discretionary	Export (SN to NSW)	15	39	8	62
	Import (NSW to SN)	9	6	0	15
Total Export (SN to NSW)		30	344	869	1243
Total Import (NSW to SN)		107	174	416	697

Data source: NEMMCO

Table D.4 shows the following:

1. Constraints on the Murray-Tumut cut-set constrain flows both north and south, but northward flows are more frequently affected by these constraints;

2. Discretionary constraints mainly affect northward flows from Snowy to NSW;

3. Binding constraints on the North Marulan cut-set limit exports from Snowy to NSW. Constraints on the South Marulan cut-set limit southward flows from NSW to Snowy;

4. North Tumut cut-set constraints restrict flows from Snowy to NSW more than flows in the reverse direction;

5. Liddell-Tomago cut-set constraints nearly always restricted flows from Snowy to NSW; and

6. In total, there is significantly greater frequency of constraints that limit flows from the Snowy region (Snowy to NSW) than flows from NSW (NSW to Snowy).

1.10.2 VIC-Snowy Interconnector

Table D.5 shows the frequency and location of binding constraints along the VIC-Snowy interconnector over the same period, for flows both to and from the Snowy region. As before, the data shows the number of 5-minute dispatch intervals in which a cut-set constraint was both binding and the most restrictive constraint on the entire interconnector. The data includes all times of the day (peak and off-peak), all four seasons (summer, autumn, winter, spring), and outage conditions (system normal, network outage).

Table D.5: Frequency of most binding constraints (No. dispatch intervals binding), VIC-Snowy interconnector (V-Snowy), System Normal & Outage conditions, 1 July 2003 to 9 May 2006

Frequency for VIC-Snowy	Year			
	2003/04	2004/05	2005/06	Grand Total
Yass Control		12		12
Nth Tumut	3			3
Wagga-Yanco			28	28
Murray-Tumut	424	45	146	615
Ded-Murray	122	64	65	251
Dederang Tx	5	2	195	202
Ded-Sth Morang		3		3
Sth Morang Tx	2,226	1,085	828	4,139
Voltage	516	194	932	1,642
Stability	7,945	6,426	1,195	15,566
Discretionary	1,491	810	428	2,729
Grand Total	12,732	8,641	3,817	25,190

Data source: NEMMCO

The following observations can be made about the data in Table D.5:

1. Stability constraints are the most frequent limitation on flows along the VIC-Snowy interconnector. For example, in 2003/04 these constraints affected 7945 dispatch intervals (or 662 hours), representing 62% of the total 12732 dispatch intervals in which the interconnector was constrained.

2. South Morang transformer constraints were the second most frequent limitation on interconnector flows.

3. Voltage constraints represent the third most frequent restriction on VIC-Snowy transfers;

4. The Murray-Tumut constraint was the fourth most frequent limiting factor on interconnector flows over the three years. However, in 2005/06 constraints on this cut-set were the sixth most frequent determinant of interconnector flows — comprising 4% of the occasions (i.e. 146/3817 dispatch intervals) when interconnector flow was at its limit.

5. Constraints between Dederang and South Morang very rarely represent the most limiting factor on interconnector flows. This result is at also odds with the Macquarie Generation proposal, which locates a regional boundary at this cut-set on the basis that it is a major “pinch point”.

6. Binding constraints on the Dederang-Murray cut-set determine the limit on interconnector flows around 1% of the time per year in each of three years;

7. South Morang transformer constraints were the seventh most frequent limitation on interconnector flows across the three years. In 2005/06 these constraints were the fifth most frequent limiting factor on interconnector flows.

8. Constraints associated with “Yass Control”, North Tumut, and Wagga Yanco are very rarely the most limiting factor on flows on the VIC-Snowy interconnector. This result appears to also be at odds with Macquarie Generation proposal, which is premised on the assumption that flow constraints between Southern NSW and Sydney are significant enough to warrant a region boundary change.

9. There has been a significant decline in the frequency of Discretionary constraints setting the interconnector limit over the three years.

Table D.6 segments the data in Table D.5 into the frequency of binding constraints limiting:

- flows north from the VIC region to the Snowy region (Exports from VIC);
- flows south from the Snowy region to the VIC region (Imports to VIC).

Table D.6: Frequency of most binding constraints by direction of flow (No. dispatch intervals binding), VIC-Snowy interconnector (V-Snowy), System Normal & Outage conditions, 1 July 2003 to 9 May 2006

Key	Data	Year 2003/04	2004/05	2005/06	Grand Total
Yass Control	Export (VIC to SN)		0		0
	Import (SN to VIC)		12		12
Nth Tumut	Export (VIC to SN)	0			0
	Import (SN to VIC)	3			3
Wagga-Yanco	Export (VIC to SN)			0	0
	Import (SN to VIC)			28	28
Murray-Tumut	Export (VIC to SN)	10	4	13	27
	Import (SN to VIC)	415	41	133	589
Ded-Murray	Export (VIC to SN)	21	0	0	21
	Import (SN to VIC)	101	64	65	230
Dederang Tx	Export (VIC to SN)	0	0	0	0
	Import (SN to VIC)	5	2	195	202
Ded-Sth Morang	Export (VIC to SN)		0		0
	Import (SN to VIC)		3		3
Sth Morang Tx	Export (VIC to SN)	1461	1072	821	3354
	Import (SN to VIC)	766	25	94	885
Voltage	Export (VIC to SN)	0	0	0	0
	Import (SN to VIC)	516	194	932	1642
Stability	Export (VIC to SN)	7945	6426	1195	15566
	Import (SN to VIC)	0	70	45	115
Discretionary	Export (VIC to SN)	309	678	351	1338
	Import (SN to VIC)	1182	330	320	1832
Total Export (VIC to SN)		9746	8180	2380	20306
Total Import (SN to VIC)		2988	741	1812	5541

Data source: NEMMCO

The following observations can be made about the data in Table D.6:

1. Stability constraints overwhelmingly limit export flows from VIC and rarely limit import flows to VIC.

2. South Morang transformer constraints are also predominantly a restriction on Victorian exports, rather than imports.

3. Voltage constraints only appear to restrict imports of power into VIC from the Snowy region;

4. Murray-Tumut cut-set constraints were almost always associated with restrictions of import into Victoria rather than exports.

5. Constraints between Dederang and South Morang were only a limiting factor on Victorian imports.

6. Dederang-Murray cut-set constraints limit imports;

7. South Morang transformer constraints tend to limit VIC exports much more so than VIC imports;

8. "Yass Control", North Tumut, and Wagga-Yanco constraints limit power flows from Snowy to VIC; and

9. Discretionary constraints affect both imports and exports from VIC.

1.10.3 Controlling for network outages

Network outages change the topology of the transmission network and alter the constraints and limits used to manage the network that remains in service. Network outages can be planned (for maintenance), forced (by fire, mechanical failure), or as a result of routine circuit switching to clear faults.

The topology and operations of the network can be divided into two broad categories:

- *System normal* — all network elements that would normally be switched into service are in service; and

- *Outage conditions* — at least on network element that would normally be switched into service is out of service.

Dividing the data on the frequency of binding constraints into these two classes enables congestion to be characterised as relating to the physical design limits of the network with, either:

- all network elements in operation (i.e. System normal); or

- one or more network elements out of operation (i.e. Outage conditions).

It is well known that binding constraints on one part of an electrical network can affect dispatch and pricing all across the entire network. The economic consequences of this depend on how persistently the constraints affect: the efficiency of economic dispatch; reliability of supply; and power system security and control.

Arguably, constraints that bind frequently under "system normal" conditions would be the leading candidates for assessment under the Regulatory Test as to whether an appropriate network upgrade is economically justified. Conversely, constraints that bind only under rare outage conditions are unlikely to justify a network upgrade if the Regulatory Test is applied.

"System normal" constraints that bind frequently may be having a material affect on dispatch, but may not be economic to build out. That is, these types of binding constraints are likely to reflect that both the network's design and its capacity are economically efficient. However, the existence of persistently binding "system normal" constraints in a regional pricing market structure may also indicate a location of "material congestion". Such "material congestion" relating to "system normal" conditions may warrant strong consideration being given to region boundary being located at that location—in order to explicitly price the congestion and improve economic efficiency of dispatch—especially if a network upgrade either fails to pass the Regulatory Test or is not physically feasible (e.g. the easement can accommodate no more lines).

Although specific outage conditions may occur relatively infrequently, they can have a significant effect on the location of congestion, its severity, the efficiency of dispatch, and the financial risks faced by market participants. Arguably, in a regional pricing market, congestion at a particular part of the network that arises under "outage" conditions may not justify a regional boundary, because although it might cause significant changes in the economic efficiency of dispatch, the outage conditions are of such limited duration or occur rarely enough, that the creation of a new pricing region is not believed to be warranted. That is, the market design (and participants) accommodates/accepts the economic inefficiencies and financial risks associated with congestion that arises from "rare" outage conditions.

Table D.7 and Table D.8 below contain data on the frequency of congestion on the Snowy-NSW (Snowy1) and VIC-Snowy (V-Snowy) interconnectors, by cut-set constraint type, for "Modified System Normal" conditions. Here "Modified System Normal" conditions means that there are no outages of the usual "System Normal" transmission topology apart from the 64-line (between Lower Tumut and Upper Tumut) being switched out of service. NEMMCO has advised that the 64-line is normally switched out of service during dispatch in order to avoid the stability problems on the VIC-Snowy and Snowy-NSW interconnectors that arise when the 64-line is switched in and Snowy region generation is high (which generally coincides with high interconnector flows). Recognising this, the ANTS constraint set used in the SOO ANTS also assumes the 64-line is normally out of service.

The mathematical difference between the data in Table D.7 and Table D.4 equals the congestion attributable solely to network outage conditions. Based on this comparison, Table D.7 reveals that for the Snowy-NSW (Snowy1) interconnector:

1. The vast bulk of binding cut-set constraints that limit Snowy-NSW interconnector flows in both directions arise under system normal conditions. Across the three years, 81% of the total instances (i.e. 1010/1243 instances) in which Snowy-NSW (export) flows were restricted occurred under system normal conditions. Similarly, 86% of the total most limiting binding constraints NSW-Snowy (import) flows occurred under system normal conditions (i.e. 605/697 instances);

2. Binding constraints on the North Marulan and South Marulan cut-sets were the most limiting constraint on interconnector flows only under outage conditions. Because of this, neither cut-set appears in Table D.7;

3. *Liddell-Tomago*: In only one dispatch interval under system normal conditions did this cut-set limit flows from Snowy to NSW. 48 out of 49 binding constraints on the Liddell-Tomago cut-set that limited export flows on the Snowy-NSW interconnector were associated with outage conditions. There were no outages in

the only time that flows from NSW to Snowy were limited by Liddell-Tomago cut-set;

4. *North Tumut*: Binding constraints on the North Tumut cut-set are associated with outage conditions. For exports, across the three years, only 1/17 constraints occurred under "system normal" conditions. For imports, the figure is 1/10;

5. *Murray-Tumut*: Nearly all the binding constraints on the Murray-Tumut cut-set that determined the interconnector flow limit occurred under "System Normal" conditions. For exports (i.e. Snowy to NSW flow), 952/1052 instances of binding constraints in the three years occurred in "System Normal" conditions. For imports, the corresponding figure is 576/602;

6. *Stability*: The bulk (91%) of stability constraints affecting imports in 2003/04 were related to outage conditions, with only 1/11 occurring under system normal conditions. In 2004/05, 50% (i.e. 14/28) of the stability constraints that determined NSW to Snowy flow limits arose under system normal conditions; and

7. *Discretionary*: Across the three years, nearly all the binding discretionary constraints (i.e. 56/62 instances) that determined Snowy-NSW export flows arose under "System Normal" conditions. For imports, all the discretionary constraints in 2004/05 occurred under outage conditions and a 9/15 of those that in 2003/04 occurred under system normal conditions.

Table D.7: Frequency of most binding constraints by direction of flow (No. dispatch intervals binding), Snowy-NSW interconnector (Snowy1), Modified System Normal conditions, 1 July 2003 to 9 May 2006

Key	Data	Year 2003/04	2004/05	2005/06	Grand Total
Liddell-Tom	Export (SN to NSW)			1	1
	Import (NSW to SN)			1	1
Nth Tumut	Export (SN to NSW)	1			1
	Import (NSW to SN)	1			1
Murray-Tumut	Export (SN to NSW)	9	249	694	952
	Import (NSW to SN)	77	107	395	579
Stability	Export (SN to NSW)	0	0		0
	Import (NSW to SN)	1	14		15
Discretionary	Export (SN to NSW)	15	33	8	56
	Import (NSW to SN)	9	0	0	9
Total Export (SN to NSW)		25	282	703	1010
Total Import (NSW to SN)		88	121	396	605

Data source: NEMMCO

Table D.8 focuses on VIC-Snowy interconnector congestion under "Modified System Normal" conditions. Comparing Table D.6 and Table D.8 reveals the following:

1. Around 80% of all binding cut-set constraints that limit VIC-Snowy interconnector flows in both directions arise under system normal conditions;

2. Binding constraints around Wagga-Yanco and Yass Control cut-sets only determined VIC-Snowy Interconnector flows under outage conditions – neither appear in Table D.8;

3. *North Tumut*: All the instances in which constraints on this cut-set determined VIC-Snowy flows occurred under system normal conditions;

4. *Murray-Tumut*: Across the three years, VIC to Snowy flows were limited by this constraint on 27 occasions, 17 of which were associated with system normal conditions. Over the three years, 50% of the instances in which flows from Snowy to VIC were determined by the Murray-Tumut cut-set constraint occurred under system normal conditions;

5. *Dederang Transformer* limits rarely set the VIC-Snowy interconnector flow limits under system normal conditions;

6. *Dederang-South Morang*: All the instances of this cut-set determining VIC-Snowy interconnector flow limits (north and south) relate to system normal conditions;

7. *South Morang Transformers*: In each year, between 65-80% of the binding constraints on South Morang transformers, which determine interconnector flow limits, occur under system normal conditions;

8. *Stability*: In total across the three years, 80% of the stability constraints on VIC-Snowy exports (12418/15566) occurred under system normal conditions. In the same period, all the stability constraints determining Snowy-VIC flows occurred under system normal conditions;

9. *Discretionary constraints*: 99% of both the import and export discretionary constraints that determined VIC-Snowy interconnector flow limitations occurred under system normal conditions. These discretionary constraints include those used to manage negative residues by "clamping" the VIC-Snowy interconnector.

Table D.8: Frequency of most binding constraints by direction of flow (No. dispatch intervals binding), VIC-Snowy interconnector (V-Snowy), Modified System Normal conditions, 1 July 2003 to 9 May 2006

		Year			Grand Total
Key	Data	2003/04	2004/05	2005/06	
Nth Tumut	Export (VIC to SN)	0			0
	Import (SN to VIC)	3			3
Murray-Tumut	Export (VIC to SN)	1	4	12	17
	Import (SN to VIC)	116	41	132	289
Ded-Murray	Export (VIC to SN)	21	0	0	21
	Import (SN to VIC)	25	64	61	150
Dederang Tx	Export (VIC to SN)		0	0	0
	Import (SN to VIC)		2	18	20
Ded-Sth Morang	Export (VIC to SN)		0		0
	Import (SN to VIC)		3		3
Sth Morang Tx	Export (VIC to SN)	1447	722	690	2859
	Import (SN to VIC)	564	15	94	673
Voltage	Export (VIC to SN)	0	0	0	0
	Import (SN to VIC)	204	157	792	1153
Stability	Export (VIC to SN)	6963	4741	714	12418
	Import (SN to VIC)	0	70	45	115
Discretionary	Export (VIC to SN)	309	676	345	1330
	Import (SN to VIC)	1182	328	314	1824
Total Export (VIC to SN)		8741	6143	1761	16645
Total Import (SN to VIC)		2094	680	1456	4230

Data source: NEMMCO

1.11 Limitations of historical data on the frequency of congestion[247]

The above information on the historical frequency and location of congestion between Victoria, Snowy and NSW should be used with caution. There are several reasons for this.

First, under the existing region boundary structure, there may exist significant points of congestion that do not appear in the historical data because generators that can affect whether the constraint binds may have the incentive and ability to adjust their generation in such a way that the constraint does not bind.

Second, past patterns of congestion may not be a good indicator of future congestion if circumstances change. Changed circumstances may arise from:

247 Drawn from: D. Biggar "On the use of Information on the Historical Frequency and Location of Constraints to Determine Region Boundaries", 26 June 2006.

- Changes in supply conditions, such as generator outages, changes in generation capacity or changes in market power, transmission outages, changes in transmission capacity and so on;

- Changes in demand conditions due to economic growth, changes in weather, changes in appliance mix (e.g. increased penetration and use of air-conditioning), or changes in demand-side responsiveness; and

- Changes in the formulation of the constraint equations used in dispatch (in particular, the re-writing of constraint equations in the “fully optimised” form).

Third, changing region boundaries – especially merging connection points into new regions, will change the bidding incentives on generators, thereby changing the flows on the network and the resulting pattern of constraints. A mere change in region boundaries could make existing persistent, material constraints disappear and/or reappear in other parts of the network.

Consequently, forward looking market modelling incorporating potential boundary options and the network constraints applying to those options is required to understand the likely patterns of congestion under a new NEM regional pricing structure and its impact on dispatch efficiency. NEMMCO-TIRC applied this modelling approach in 1997 and the Commission has also committed to this approach to evaluate the various options for region boundary changes.