THE NEM CONSTRAINT REPORT 2011

PREPARED BY: Ben Blake

DOCUMENT REF: ESOPP_30

VERSION: 1

DATE: 16 February 2012

FINAL

Contents

1 Disclaimer

This document is made available to you on the following basis:

a) Purpose – This Constraint Report (Report) has been produced by the Australian Energy Market Operator Limited (AEMO) to provide information about constraint equation performance and related issues as at the date of publication.

b) No substitute – This Report is not a substitute for, and should not be read in lieu of, the National Electricity Law (NEL), the National Electricity Rules (Rules) or any other relevant laws, codes, rules, procedures or policies. Further, the contents of this Report do not constitute legal or business advice and should not be relied on as a substitute for obtaining detailed advice about the NEL, the Rules, or any other relevant laws, codes, rules, procedures or policies, or any aspect of the national electricity market or the electricity industry.

c) No Warranty – While AEMO has used due care and skill in the production of this Report, neither AEMO, nor any of its employees, agents and consultants make any representation or warranty as to the accuracy, reliability, completeness or suitability for particular purposes of the information in this Report.

d) Limitation of liability - To the extent permitted by law, AEMO and its advisers, consultants and other contributors to this Report (or their respective associated companies, businesses, partners, directors, officers or employees) shall not be liable for any errors, omissions, defects or misrepresentations in the information contained in this Report, or for any loss or damage suffered by persons who use or rely on such information (including by reason of negligence, negligent misstatement or otherwise). If any law prohibits the exclusion of such liability, AEMO's liability is limited, at AEMO's option, to the re-supply of the information, provided that this limitation is permitted by law and is fair and reasonable.

2 Definitions

ABBREVIATION	DEFINITION
CFG	Constraint formulation guidelines
Constraint equation	These are the mathematical representations that AEMO uses to model power system limitations and FCAS requirements in NEMDE.
Constraint function	A group of RHS terms that can be referenced by one or more constraint equation RHSs. These are used where a common calculation is required multiple times (such as a complex stability limit or a calculation for a sub-regional demand). These have been referred to as generic equations, base equations or shared expressions in the past.
Constraint set	A grouping of constraint equations that apply under the same set of power system conditions, either for system normal or plant outage(s). AEMO uses constraint sets to efficiently activate / deactivate constraint equations.
CVP	Constraint violation penalty factor
DNSP	Distribution network service provider
EMS	Energy management system
FCAS	Frequency control ancillary service
FCSPS	Frequency control system protection scheme
LHS	Left hand side of a constraint equation. This consists of the variables that can be optimised by NEMDE. These terms include scheduled or semi-scheduled generators, scheduled loads, regulated Interconnectors, MNSPs or regional FCAS requirements.
Limit equation	A mathematical expression describing a limitation on a part of the transmission or distribution

ABBREVIATION	DEFINITION
	network. These are provided to AEMO by both TNSPs and DNSPs.
Mainland	The NEM regions: Queensland, New South Wales, Victoria and South Australia
MNSP	Market network service provider
MPC	Market price cap (previously called VOLL)
NEM	National electricity market
NEMDE	National electricity market dispatch engine
PASA	Projected assessment of system adequacy
RHS	Right Hand Side of a constraint equation. The RHS is calculated and presented to the solver as a constant; these terms cannot be optimised by NEMDE.
RTCA	Real time contingency analysis. This is an application in AEMO's EMS that continually monitors the pre and post contingent element flows and alerts if element ratings are exceeded. The RTCA has a list of elements (approximately 2000 are normally active) of which each is tripped in turn and a power flow run. RTCA reports any elements that exceed their NORM, EMER or LDSH element rating pre-contingent, and any elements that exceed their EMER or LDSH rating post-contingent. The list can also include multiple element trips for cases where these are classified as credible contingencies.
SCADA	Supervisory control and data acquisition. Information such as line flows and generator outputs are delivered via SCADA.
System normal	The configuration of the power system where: • All transmission elements are in service, or • The network is operating in its normal network configuration
TNSP	Transmission network service provider

3 References

- Congestion information resource: http://www.aemo.com.au/electricityops/congestion.html
- Previous annual constraint reports: http://www.aemo.com.au/electricityops/0200-0006.html
- Monthly constraint reports: http://www.aemo.com.au/electricityops/0100-0016.html
- Constraint naming guidelines: http://www.aemo.com.au/electricityops/200-0141.html
- Constraint formulation guidelines (CFG): http://www.aemo.com.au/electricityops/170-0040.html
- Constraint implementation guidelines (CIG): http://www.aemo.com.au/electricityops/0100-0015.html
- Constraint violation penalty factors: http://www.aemo.com.au/electricityops/140-0011.html
- Reliability panel frequency operating standards: http://www.aemc.gov.au/Market-Reviews/Completed/Review-of-Mainland-Frequency-Operating-Standards-during-Periods-of-Supply-Scarcity.html
- MMS data model: http://www.aemo.com.au/data/market_data.html#data_model

4 Introduction

Constraint equations are used by AEMO to model the power system limitations in NEMDE and PASA. This report details constraint equation performance and transmission congestion related issues for the calendar year 2011. It includes the drivers on constraint equation changes in 2011, analysis of binding and violating constraint equations, market impact of constraint equations, the constraint equations that set interconnector limits, duration of outages and information on other constraint related issues.

This annual report has been developed for both internal AEMO requirements and as a part of the congestion information resource (CIR). AEMO welcomes comments and suggestions on the content of this report from both internal AEMO staff and participants.

The 2011 report includes a number of additions compared to the 2010 report. These include:

- a graph of binding hours for system normal versus outage constraint equations
- More analysis of the trends on market impact of constraint equations
- Interconnector limit graphs now include the previous year’s flows and binding hours
- Statistics on network outage submit times

5 Current statistics

This section details the current totals of the constraint sets, equations and functions.

As of 31st December 2011 there were:

- 3657 constraint sets. This is a small increase over 2010’s total of 3559 and a smaller increase than the increase between 2009 and 2010 (2009’s total was 3431).
- 9523 constraint equations which is a similar increase (of approximately 600) to the yearly increases since 2008. 2010’s total was 8902 with 8275 in 2009 and 2008’s total was 7697. A number of the 9523 constraint equations were found to no longer be required or no longer in active constraint sets and it is expected this number will drop to approximately 9000 in early 2012.
- 390 constraint functions which is a minor increase over 382 in 2010 and 2009’s 347.

Excluded from these totals are any constraint sets, equations or functions that were archived and any that are for outage ramping. The outage ramping constraint sets and constraint equations are not built by the constraint builders but are for single use and generated by an application used by AEMO’s control room staff.

The following graphs exclude outage ramping (which would swamp the results), constraint automation built constraint equations (full results are in Figure 25) as well as any constraint equations which are not in a constraint set (and therefore cannot be active in NEMDE). These graphs show the breakup of constraint equation by regions, FCAS and a few other types (Figure 1) and by limit type (Figure 2).

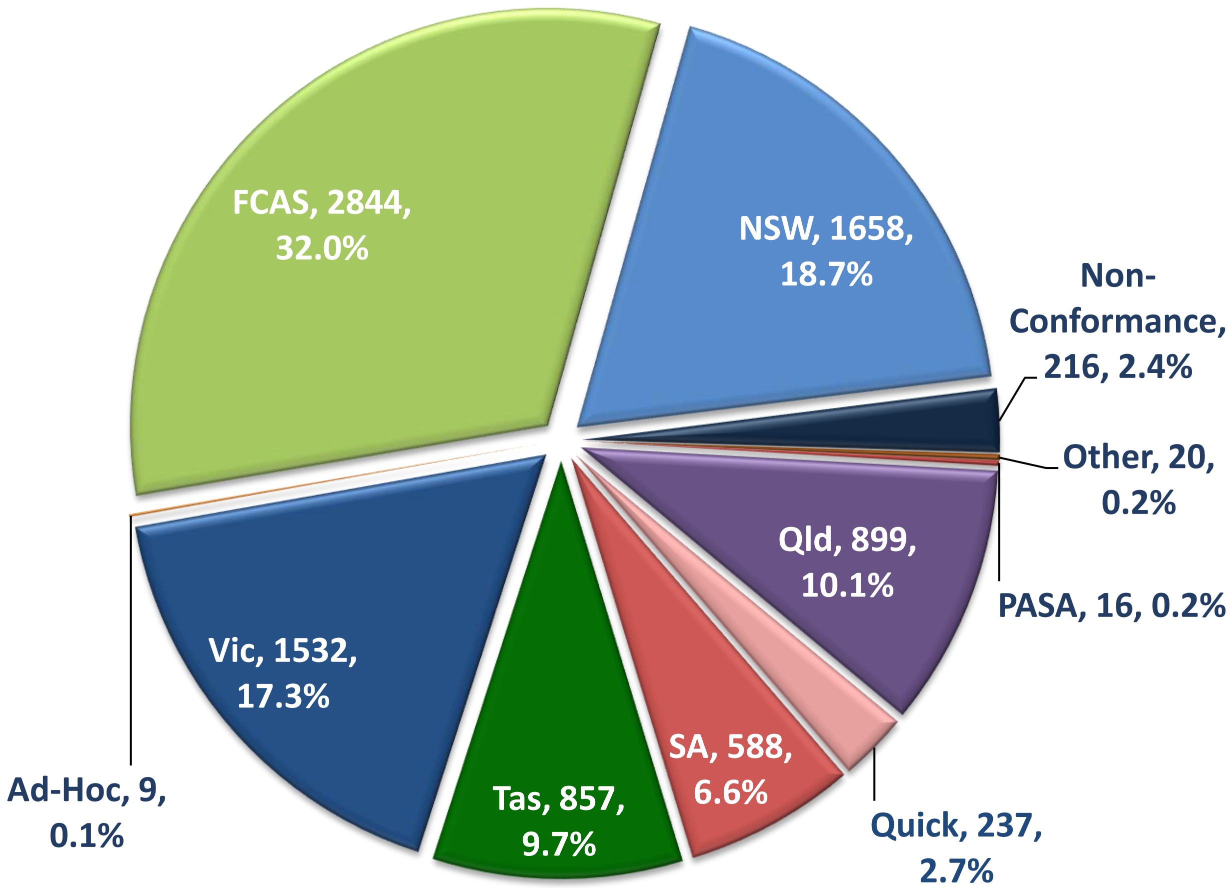

Figure 1: Constraint equations by region/FCAS

As can be seen in Figure 1 the majority of the constraint equations are for frequency control ancillary services (FCAS), NSW and then Victoria. The main types of constraint equations are for thermal overloads (28.3 %) and FCAS (22.3 %) which can be viewed in Figure 2 below.

Quick constraint equations (in Figure 1) are produced by AEMO's electricity control room staff for a selected number of LHS terms and a constant RHS value. IDs for quick constraints are prefixed with "#". Ad-Hoc constraint equations are also created by AEMO's electricity control room staff. However, these were mainly for a large number of LHS terms and software that creates quick constraints now handles more complex LHSs and ad-hoc constraint equations are rarely built. Ad-Hoc constraint equations have an ID prefixed with "@".

The limit type of "DEFAULT" (see Figure 2 below) is only used on very old constraint equations which pre-date the addition of the limit type field. All constraint equations on implementation of the new field were set to "DEFAULT".

Compared to 2010 there were a number of changes to the percentage breakup of the constraint equations in 2011. These differences include:

- The number of NSW constraint equations decreased from 1742 to 1658. This due to the removal of a number of constraint equations which were no longer required following the western 500 kV augmentation.
- Queensland decreased from 919 to 899
- Small increases in SA constraint equations (557 to 588) and Tasmania (820 to 857)
- A large increase in Victorian constraint equations from 1368 to 1542
- Very few changes in the limit types except the number of thermal constraint equations has decreased slightly from 2402 to 2372.

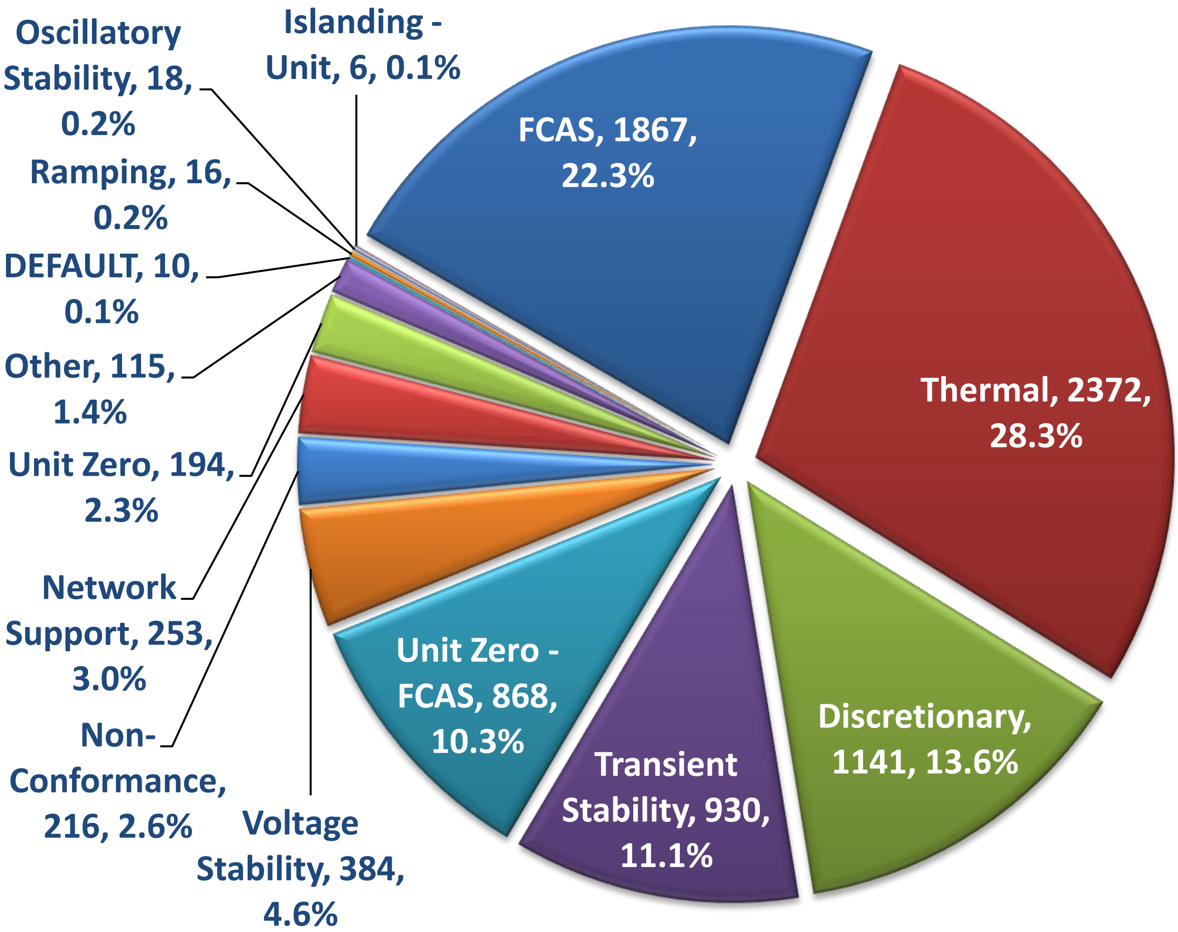

Figure 2: Constraint equations by limit type

6 Constraint equation changes

One of the main drivers for changes to constraint equations is from power system change, whether this is the addition or removal of plant (either generation or transmission). The addition of a new generator, to either the left hand side (LHS) or right hand side (RHS) of a constraint equation, can cause multiple constraint equation changes. Prior to September 2011 AEMO's constraint builders were only able to include generator(s) in constraint equations once the generator(s) were registered in AEMO's market systems. As transmission network modifications (where the new generator's substation is cut into existing lines) and the generator registration usually occur at different times this would generate multiple constraint equation changes.

Following a software change in September 2012 AEMO's constraint builders are now able to include a generator in a constraint equation before it is registered. This is expected to reduce the number of constraint changes in 2012.

The tables in this section list the substation work and generator registration separately. Only changes on the main transmission system, normally those that directly cause changes to the constraint equations, are listed.

2009 included a significant number of new generators commissioned across all regions. 2010 and 2011 were markedly different with only a few new generators commissioned (4 in 2010 and 5 in 2011) compared to 13 in 2009. The number of transmission element changes in 2011 was higher than 2010 (21 versus 17) and the same number of changes as in 2009. The most significant change causing constraint equation changes was the commissioning of the Lindisfarne to Waddamana 220 kV lines in Tasmania.

2011's number of constraint changes was less than the 6250 in 2010 and the lowest since 2004 (which had 4159) - see Figure 3. The greatest number of constraint equation changes was 8592 in 2009. The number of changes in 2011 is below the 10 year average of 5200 changes.

6.1 Generators

The following list includes all scheduled and semi-scheduled generators that were added or removed in 2011. Additionally where non-scheduled wind-farms were of a significant size and caused constraint changes these are listed also.

Five new generators were registered in 2011along with several existing generators de-registering in Queensland. For the first time in a number of years a new generator was registered for FCAS.

Table 1: Generator changes in 2011

GENERATOR	REGISTRATION DATE	REGION	NOTES
Gunning wind farm	25 March 2011	NSW	
Woodlawn wind farm	3 May 2011	NSW	
Callide A2	17 May 2011	Queensland	Units de-registered
Callide A4	17 May 2011	Queensland	Unit re-registered as non scheduled
Swanbank B2 & B4	1 July 2011	Queensland	Units de-registered
The Bluff wind farm	5 July 2011	South Australia	
Mortlake (1 & 2)	1 August 2011	Victoria	
Oaklands Hill wind farm	5 August 2011	Victoria	
Tamar Valley CCGT	22 December 2011	Tasmania	Re-registered to include FCAS services

6.2 Transmission

In 2011 there were a slightly larger number of transmission changes compared to 2010 (22 versus 19). The most significant change was the commissioning of the double circuit 220 kV line from Lindisfarne to Waddamana in Tasmania. Similar to 2009 and 2010, the majority of projects were in Queensland. New South Wales had no projects compared to 2009/10.

Table 2: Transmission changes in 2011

PROJECT	DATE	REGION	NOTES
Blackwall - Swanbank (801 and 803) 275 kV lines	11 April 2011	Queensland	Lines decommissioned
Lindisfarne - Waddamana No. 1 & No. 2 220 kV line	20 April 2011	Tasmania	Lindisfarne - Waddamana 220 kV augmentation [1]
Lindisfarne 220 kV / 110 kV T5 transformer	20 April 2011	Tasmania	Lindisfarne - Waddamana 220 kV augmentation
Lindisfarne 220 kV / 110 kV T4 transformer	28 April 2011	Tasmania	Lindisfarne - Waddamana 220 kV augmentation
Mortlake switching station	23 May 2011	Victoria	Cut into the existing Heywood - Moorabool #2 500 kV line. This is the connection point for the new Mortlake power station.
Mt Barker South 275 kV substation	1 June 2011	South Australia	Cut into the existing Cherry Gardens - Tungkillo 275 kV line
Millmerran 200 MVAr cap bank	14 July 2011	Queensland	
Templers West 275 kV	16 July 2011	South Australia	

[1] http://www.transend.com.au/ourprojects/current/waddamana_transmissionline/

PROJECT	DATE	REGION	NOTES
substation			
Western Downs 275 kV substation	28 July 2011	Queensland	Energised via Braemar - Western Downs (8864) 275 kV line
Braemar - Western Downs (8864) 275 kV line	28 July 2011	Queensland	
Middle Ridge 330 kV cap bank (#3)	1 August 2011	Queensland	
Braemar - Western Downs (8820) 275 kV line	24 August 2011	Queensland	
Wemen terminal station	12 September 2011	Victoria	220/66 kV substation cut into the Red Cliffs - Kerang line
Ingham South - Yabulu South (7133) 132 kV line	5 October 2011	Queensland	Replacement for decommissioned line constructed at 275 kV running at 132 kV
Cardwell - Yabulu South (7132) 132 kV line	8 October 2011	Queensland	Replacement for decommissioned line constructed at 275 kV running at 132 kV
Decommission Ingham South - Tully tee Cardwell (7134) 132 kV line	10 October 2011	Queensland	Decommissioned and replaced by new line
Cardwell - Ingham South (7388) 132 kV line	26 October 2011	Queensland	Replacement for decommissioned line constructed at 275 kV running at 132 kV
Kareeya - Tully (7135) 132 kV line	2 November 2011	Queensland	
Raglan 275 kV substation	25 November 2011	Queensland	
Middle Ridge 330 kV cap bank (#4)	25 November 2011	Queensland	120 MVAr capacitor
City West substation and 275 kV cable	2 December 2011	South Australia	New 275 kV cable from Torrens Island B to new City West substation[2]

6.3 Comparison of constraint equation changes

The following 2 graphs compare the yearly and monthly constraint equation changes. Figure 3 includes a comparison with the total number of constraint equations at the end of each calendar year and Figure 4 includes the total number of changes in 2011 per month. Both Figure 3 and Figure 4 are cumulative area graphs so the NEM yearly / monthly totals are indicated by NSW.

The graphs do not include changes to the constraint sets or constraint functions or any archiving. The number of times a constraint equation changes is not an accurate reflection of the amount of work involved in changing it (some changes are to fix a description; some changes are more complex and can require many days of work). These results measure when the changes occurred and not when they became active, so the FCAS change that was made active on 1st Jan 2009 but was loaded into the database in late 2008 is included in the 2008 results and not the 2009 results.

[2] http://www.electranet.com.au/network/current-planned-developments/near-metro/adelaide-central-reinforcement/

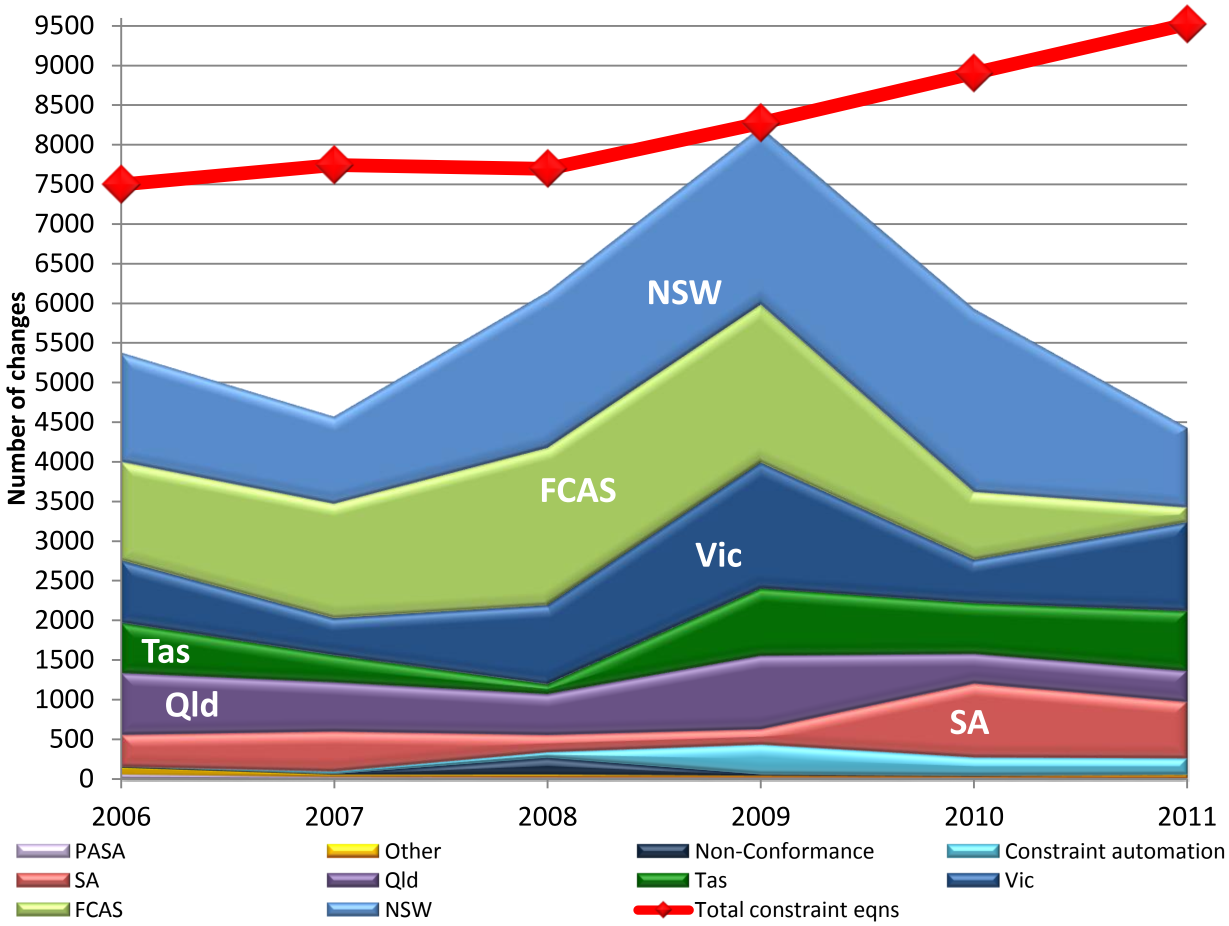

Figure 3: Constraint equation changes per calendar year

As can be seen from Figure 3 the number of constraint changes increased steadily between 2007 and 2009 but fell in 2010 and 2011. 2011 had the lowest number of constraint equation changes (4775) since 2004 (which had 4158 changes). The years with a large number of constraint equation changes are due to:

- the program to convert constraint equations to “fully co-optimised” in 2006
- the Snowy region abolition in 2008
- the multiple stages of the NSW western 500 kV project in 2009 and partly into 2010

The reduction in FCAS constraint equation changes is due to no power system or market changes impacting on FCAS. In previous years the large number of changes were due to co-optimisation of regulation and 5 minute services (2008), Snowy abolition (2008) and Tasmanian frequency operating standards changing (2009).

The 10 year average of constraint equation changes is 5200. It is expected that 2012 will have a smaller number of changes than this average and the number of changes will be similar or smaller than 2011.

Figure 4 shows the constraint equation changes per month in 2011 versus the total changes in 2010 and 2009. Much like the previous 2 years each region had bursts of activity in constraint equation changes. The major groups of constraint equation changes were due to transmission and generation changes (see Table 1 & Table 2):

- Tasmania in April / May – Lindisfarne to Waddamana 220 kV line commissioning
- NSW in May – Woodlawn and Gunning registration and commissioning
- Qld in May / June – de-registering of Callide A and Swanbank B2 and B4

- SA in July / August – commissioning of The Bluff wind farm
- Vic in August – commissioning of Mortlake power station
- Tasmania in October / November – new constraint equations to manage issues with the network control system protection scheme (NCSPS) [3]
- SA in December – Angaston re-registration as a non-scheduled unit (this change did not become active until 1 Jan 2012)

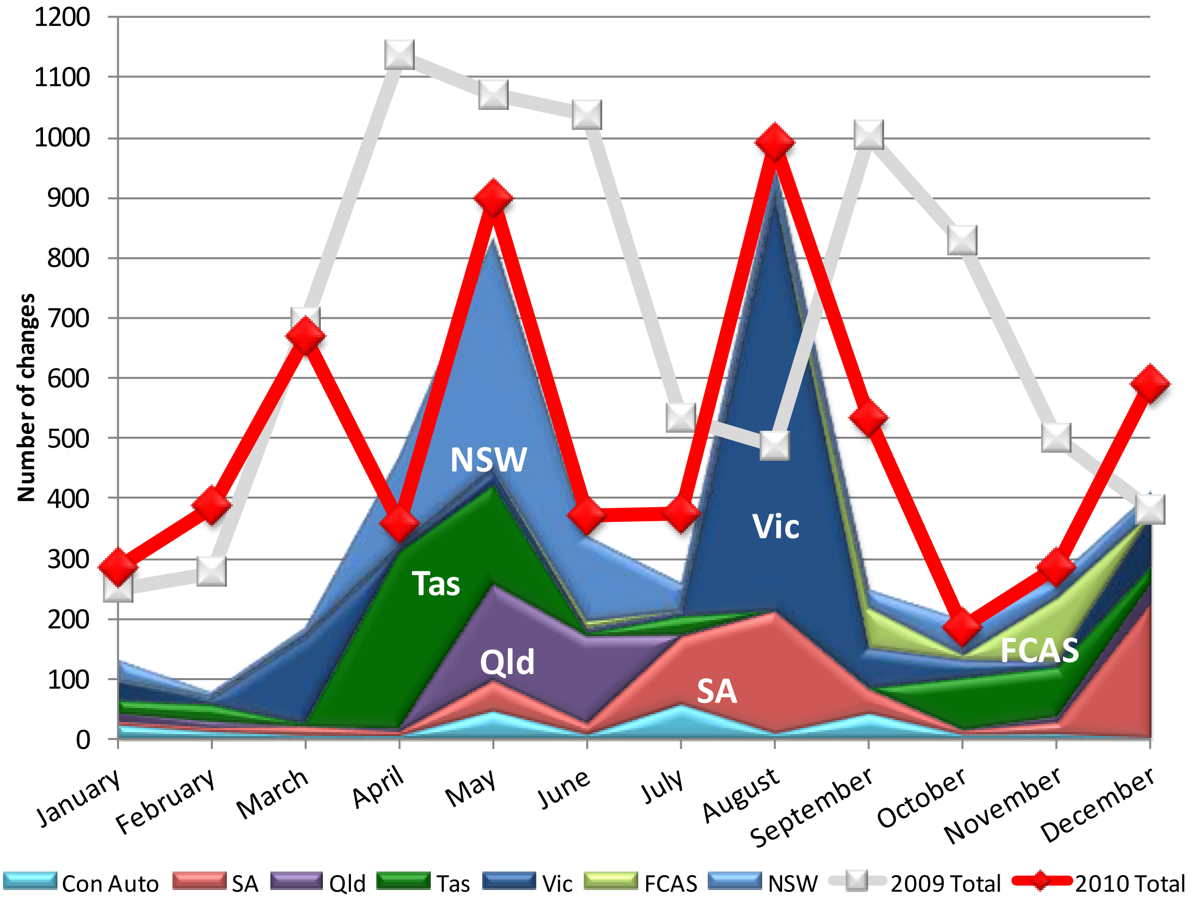

Figure 4: Constraint equation changes per month in 2011

7 Binding and violating

In this section of the report the top 20 binding and violating constraint equations are examined. System normal constraint equations are in bold and the number of hours for 2010 (if any) is indicated in brackets below the 2011 hours. In the tables a brief description of the constraint equation is given (in *italics*) along with any comments. If the full description, LHS or RHS of the constrain equation is required then this can be obtained from either the plain English converter[4] on the MMS web portal or via the MMS data model[5].

7.1 Binding constraint equations

When a constraint equation is binding either flows have reached the thermal or stability limit or the FCAS constraint equation is setting an FCAS requirement. As there is at least one constraint equation setting the FCAS requirement for each of the 8 services at any time this leads to many

[3] http://www.aemo.com.au/reports/0232-0112.html
[4] https://mms.prod.nemnet.net.au/Mms/login.aspx
[5] http://www.aemo.com.au/data/market_data.html#data_model

more hours of binding for FCAS constraint equations. These would dominate the top 20. Due to this the FCAS and network binding results have been separated into two tables (see Table 3 and Table 4 below).

Some constraint equations only bind at certain times of the year (such as winter or summer) and Figure 5 shows a monthly breakup for the top 10 binding network constraint equations. In 2011 the top 10 binding constraint equations were more likely to bind in the second half of the year with sharp peaks in June, July and November.

In some cases the binding results for several constraint equation IDs have been combined. This is due to some limits being represented by several constraint equations to either:

- Linearise non-linear terms so they can be included on the LHS (such as the Victoria to NSW transient stability limit)
- Move each generator from a maximum calculation onto the LHS of separate constraint equations (such as the NSW to Qld voltage stability limit)
- Manage the same limit under different network configurations (such as Yallourn W1 switched into 500 kV or 220 kV mode)
- Combining different values of network support for the same generator(s)

Out of the top 20 binding results (see Table 3 and Table 4 below) the majority are system normal constraint equations and not those for outage cases.

7.1.1 Network constraint equations

Table 3: Top 20 binding network constraint equations

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
V::N_NILVxxx & V::N_NILQxxx	1,132 (544)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* There are 12 constraint equations that make up the transient stability export limit from Victoria and all the binding results have been combined.
V^^S_NIL_NPS_SE_OFF & V^^S_NIL_NPS_SE_ON & V^^S_TBCP_NPS_SE_OFF & V^^S_TBCP_NPS_SE_ON & V^^S_NIL_MAXG_AUTO & V^^S_NIL_MAXG_SECP	1,121 (577)	*Out = Nil, Victoria to SA long term voltage stability limit for loss of the largest credible generation contingency in SA, South East capacitor bank on / off, Tailem Bend capacitor bank on/off* In 2011 there were 6 constraint equations that made up the voltage stability limit from Victoria to South Australia and the binding results from all these have been combined. The first 4 constraint equations were for the loss of a Northern unit and these were replaced on 1 December 2011 by 2 new constraint equations for the loss of the largest generation contingency in SA. Whilst the change to using the largest generation contingency has increased the transfer limit it is expected the “MAXG” constraint equations will bind for a large number of hours in 2012.
N_X_MBTE2_A & N_X_MBTE2_B	797 (1,175)	*Out = two Directlink cables* Two of the Directlink cables were out for a large period of 2011 (90 days) and 2010 (121 days) – see Table 19
NSA_Q_GSTONE34_xxx	695 (0)	*Gladstone 3 + 4 >= various levels for Network Support Agreement* The binding results from 7 constraint equations that set the minimum level of Gladstone 3 and 4 generation have been combined. The majority of the binding hours for these constraint equations were in July (223 hours) and November (374 hours) - see Figure 5. These constraint equations were invoked for 54.3 days in 2011 compared to 5.6 days in 2010.
T_TAMARCCGT_GCS	647 (298)	*Limit output of Tamar Valley Power Station based on load available for shedding by Tamar Valley 220 kV generation control scheme (GCS)*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		The Tamar Valley output is dependent on the GCS so it is expected that this constraint equation will bind for a high number of hours in 2012.
N_X_MBTE_3A & N_X_MBTE_3B	350 (342)	*Out= all three Directlink cables* All three of the Directlink cables were out for a similar period in 2010 and 2011 (14.5 and 14.2 days – see Table 19).
V^^S_KHKN_MAXG_SEOFF & V^^S_KHKN_MAXG_SEON	301 (0)	*Out = Keith to Kincraig 132 kV line, Victoria to SA long term voltage stability limit for loss of a Northern unit, South East capacitor bank on / off* There are 2 constraint equations that make up the voltage stability export limit from Victoria to South Australia and all the binding results have been combined. These constraint equation IDs were new in 2011, however the constraint equations they replaced were not invoked in 2010 and they did not bind in 2009. The Keith to Kincraig 132 kV line was out for 28.5 days in 2011 (see Table 19) and without this outage the system normal voltage stability limit would have been the top binding constraint equation for 2011.
Q>>NIL_855_871	217 (470)	*Out = Nil, avoid overload on Calvale to Wurdong (871) 275 kV line on trip of Calvale to Stanwell (855) 275 kV line* This constraint equation is expected to bind for a similar amount in 2012 and for the next several years until Powerlink constructs double circuit 275kV lines between Calvale and Stanwell in late 2013[6].
S>>V_NIL_SETX_SETX	207 (214)	*Out = Nil, avoid overloading a South East 275/132 kV transformer on trip of the remaining South East 275/132 kV transformer* This constraint equation binds when there is export from South Australia to Victoria and high generation from the wind farms and gas turbines in the south east of South Australia.
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	207 (311)	*Out = Nil, avoid overloading the South Morang 500/330 kV (F2) transformer for no contingencies, for radial/parallel modes and Yallourn W1 on the 500 or 220 kV* These constraint equations maintain flow on the South Morang F2 transformer below its continuous rating. It is expected that the combination of these 3 constraint equations will bind for a similar amount in 2012.
V_T_NIL_FCSPS	193 (1,191)	*Basslink limit from Victoria to Tasmania for load enabled for the Basslink frequency control special protection scheme (FCSPS)* This constraint equation binds when there is high import to Tasmania or a low amount of load is enabled for tripping.
S>V_NIL_NIL_RBNW	175 (141)	*Out = Nil, avoid overloading the North West Bend to Robertstown 132 kV line on no line trips* This constraint equation normally sets the upper limit on Murraylink and is expected to bind with similar frequency in 2012.
NC_V_APS	167 (72)	*Non Conformance Constraint for Anglesea Power Station*
V>>V_NIL1A_R	159 (7)	*Out = Nil, avoid overloading a South Morang to Dederang 330 kV line for trip of the parallel line* This constraint equation bound mainly in the summer and winter months and for flows from Victoria to NSW.
N^N_KKLS_1	132 (0)	*Out = Koolkhan to Lismore (967) 132 kV line, avoid voltage collapse on trip of Coffs Harbour to Lismore (89) 330 kV line* This new constraint equation was added in September 2011 (after updated advice from TransGrid) and replaced N>N-KKLS_TE_1 (which

[6] http://www.powerlink.com.au/Projects/Central/Calvale_to_Stanwell.aspx

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		bound for 174 hours in 2010 and 99 hours in 2011). The Koolkhan to Lismore 132 kV line was out for 21.9 days in 2011 which was similar to 2010's 25.4 days (see Table 19). Tripping of 89 line leaves Lismore connected by the Tenterfield to Lismore (96L) 132 kV line. 96L is the weaker of the 2 lines into Lismore and support is usually required from Terranora interconnector. It is expected that this constraint equation will continue to bind for a reasonable portion of any future outage times.
S>>V_NIL_WTTP_WEMW4	131 (23)	*Out = Nil, avoid overloading the Waterloo East to Morgan Whyalla pump 4 132 kV line on trip of the Waterloo to Templers 132 kV line* This constraint equation bound consistently until advice (in August 2011) from ElectraNet that on the operation of the Waterloo runback scheme (also see S>>V_NIL_RBTXW_RBTX1).
N>N-KKLS_TE_2	130 (0)	*Out = Koolkhan to Lismore (967) 132 kV line, avoid overloading the Armidale to Glen Innes (96T) 132 kV line on trip of Coffs Harbour to Lismore (89) 330 kV line* See note on N^N_KKLS_1.
S>>V_NIL_RBTXW_RBTX1	124 (0)	*Out = Nil, avoid overloading Robertstown #1 275/132 kV transformer on trip of the Robertstown #2 275/132 kV transformer* This constraint equation was added in August 2011 based on advice from ElectraNet on the operation of the Waterloo wind farm runback scheme. Since it was implemented it has bound consistently and would be expected to have a high number of hours in 2012.
V>>N-NIL_HA	105 (461)	*Out = Nil, avoid overload on Murray to Upper Tumut (65) 330 kV line on trip of Murray to Lower Tumut (66) 330 kV line* This constraint equation binds for high flows from Victoria to NSW and most of the hours were accumulated in January and February 2011. Most of the 2010 hours were in November and December.
Q:N_NIL_BI_POT	103 (252)	*Out = Nil, avoid transient instability for a trip of a Boyne Island potline (400 MW)* For high flows from Queensland to NSW either this constraint equation or Q:N_NIL_OSC or Q:N_NIL_BCK2L-G will bind.

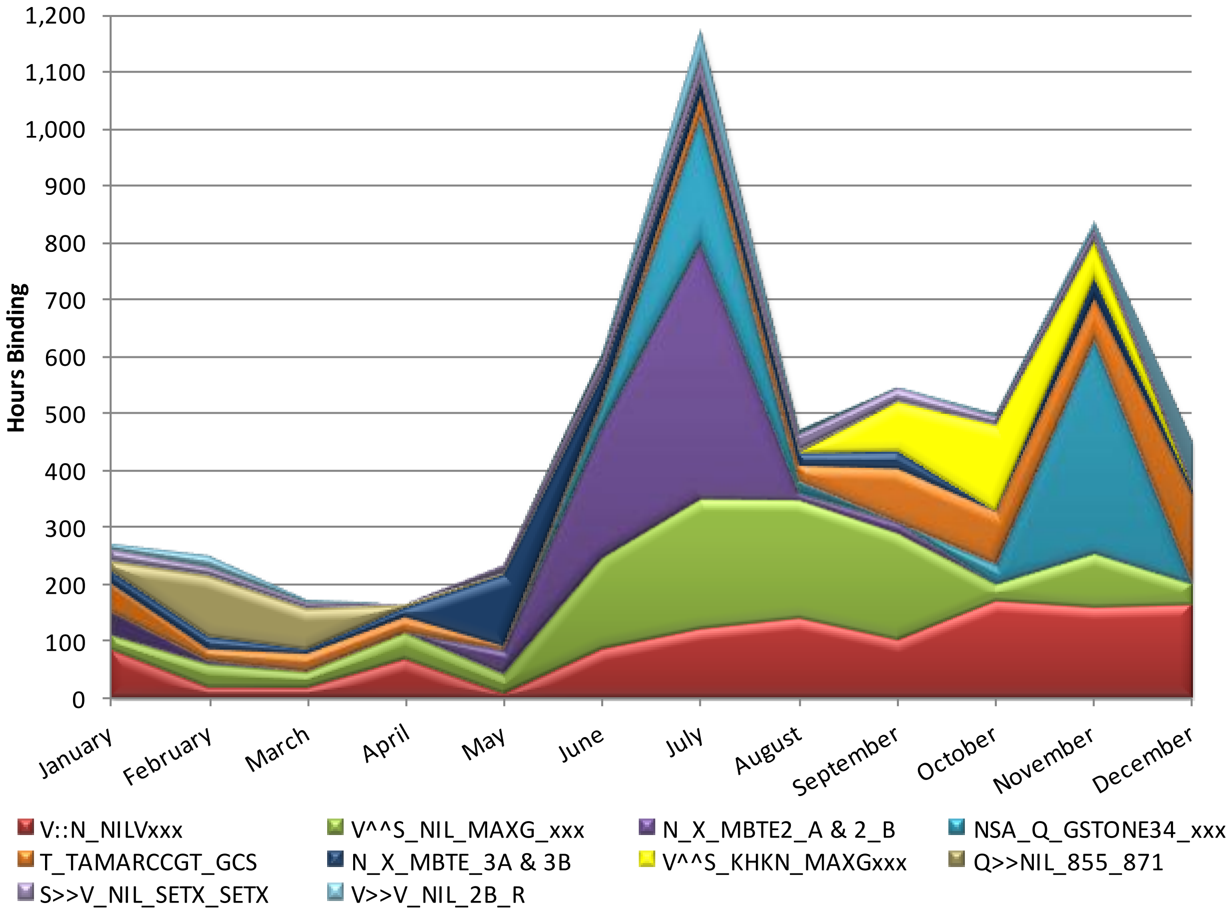

Figure 5: Top 10 binding constraint equations per month

7.1.2 FCAS

In general for FCAS constraint equations it is expected that the system normal constraint equations will continue to be in the top 20 binding list unless there are transmission outages for significant periods of time requiring FCAS. For the Basslink trip constraint equations (such as F_T+NIL_BL_R6_1) these only bind when Basslink is transferring into Tasmania so the binding hours will reflect this.

Table 4: Top 20 binding FCAS constraint equations

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
F_I+NIL_MG_R5	8,063 (7,945)	*NEM raise 5 minute requirement for a NEM generation event* The largest unit is usually Kogan Creek or one of the large NSW units.
F_I+NIL_MG_R6	7,612 (7,501)	*NEM, raise 6 second requirement for a NEM generation event*
F_I+NIL_DYN_LREG	7,443 (7,861)	*NEM lower regulation requirement*
F_I+NIL_MG_R60	7,440 (7,356)	*NEM raise 60 second requirement for a NEM generation event*
F_I+ML_L5_0400	7,109 (5,939)	*NEM lower 5 minute requirement for a NEM load event* The largest single load in the NEM is 400 MW at Boyne Island in Queensland.
F_T+NIL_BL_R6_1 & F_T++NIL_BL_R6_x	2,801 (3,963)	*Tasmania raise 6 second requirement for loss of Basslink, FCSPS available* In November 2011 the 4 constraint equations were replaced with 2

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		constraint equations due to advice that the loss of link time on Basslink was changed to 400ms. The binding results from all the constraint equations have been combined.
F_T++NIL_TL_L60	2,498 (2,237)	*Tasmania lower 60 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_I+ML_L6_0400	2,323 (2,603)	*NEM lower 6 second requirement for a NEM load event* See note on F_I+ML_L5_0400
F_T+NIL_BL_R60_1 & F_T++NIL_BL_R60_x	2,245 (3,020)	*Tasmania raise 60 second requirement for loss of Basslink, FCSPS available* See note for F_T+NIL_BL_R6_1 & F_T++NIL_BL_R6_x
F_MAIN++ML_L5_0400	2,115 (1,161)	*Mainland lower 5 minute requirement for a mainland load event, Basslink able transfer FCAS* See note on F_I+ML_L5_0400
F_T++NIL_TL_L6	2,000 (1,736)	*Tasmania lower 6 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_MAIN++NIL_BL_L60	1,976 (1,955)	*Mainland lower 60 second requirement for loss of Basslink, Basslink flow into Tasmania, Basslink able to transfer FCAS*
F_I+NIL_DYN_RREG	1,742 (418)	*NEM raise regulation requirement*
F_T++NIL_MIG_R5	1,569 (954)	*Tasmania raise 5 minute requirement for a Tasmania generation event (loss of the largest inertia), Basslink able to transfer FCAS*
F_MAIN++ML_L6_0400	1,492 (1,580)	*Mainland lower 6 second requirement for a mainland load event, Basslink able transfer FCAS* See note on F_I+ML_L5_0400
F_T+NIL_BL_R5	1,208 (1,241)	*Tasmania raise 5 minute requirement for loss of Basslink, FCSPS available*
F_MAIN++NIL_MG_R60	1,184 (1,162)	*Mainland raise 60 second requirement for a mainland generation event, Basslink able transfer FCAS*
F_I+ML_L60_0400	1,125 (1,484)	*NEM lower 60 second requirement for a NEM load event* See note on F_I+ML_L5_0400
F_T++RREG_0050	933 (939)	*Tasmania raise regulation requirement greater than 50 MW, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R6	811 (817)	*Mainland raise 6 second requirement for a mainland generation event, Basslink able transfer FCAS*

7.1.3 Binding trends

Figure 6, Figure 7 and Figure 8 show the binding constraint equations categorised by region, limit type and system normal/outage for the past 6 years. The FCAS in Figure 7 excludes the system normal FCAS constraint equations (as these would dominate the graph). Binding FCAS hours (whether system normal or outage) are excluded from Figure 8 for the same reason. The trends indicated by these two graphs are:

- There was a peak in 2008 and a secondary peak in 2011 in the total number of binding hours
- NSW and South Australia have increased in the number of binding hours since 2006
- Queensland and Victoria have decreased the number of binding constraint hours since 2006, although there was a spike for Queensland in 2010

- Tasmania has increased since 2006 however, it peaked in 2010 and the binding hours in 2011 are less than 2009
- Voltage stability constraint equations are binding more compared with 2006 (643 hours versus 2091 hours in 2011).
- Thermal overload constraint equations for most years bound between 3000 and 4000 hours with a large increase in 2010 of 5134 hours and a decrease of 2555 hours in 2008
- Transient stability binding constraint equations have increased steadily from 911 hours in 2006 to 1618 hours in 2011 with a spike in 2010 of 2243 hours.
- Binding hours due to outages of Directlink cables increased from 238 hours in 2006 to a peak of 1997 hours in 2010
- Overall binding hours (excluding FCAS) has been slowly declining in the past 6 years
- The number of outage binding hours has been less than the system normal binding hours since 2008
- System normal binding hours has been declining since a peak of 9742 hours in 2008

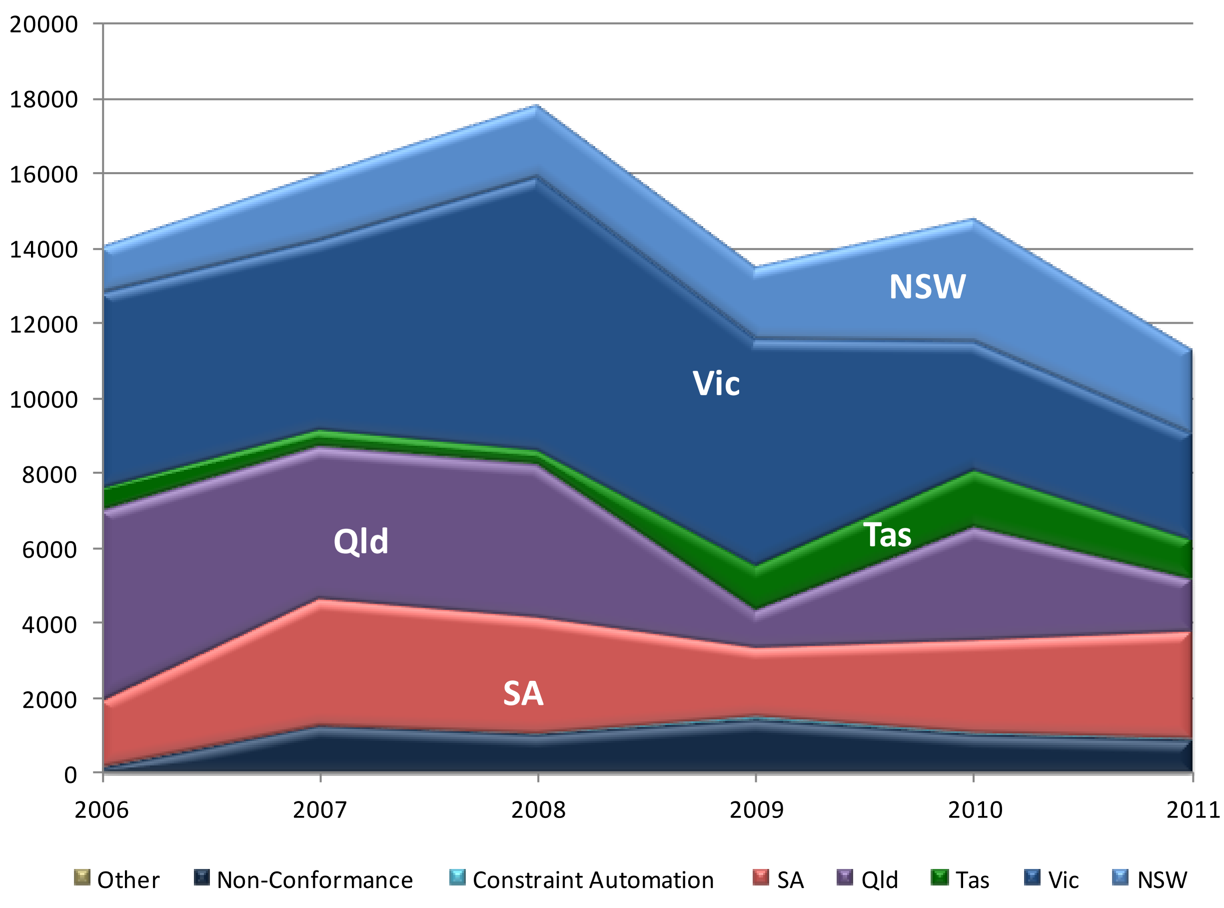

Figure 6: Binding constraint equations by region

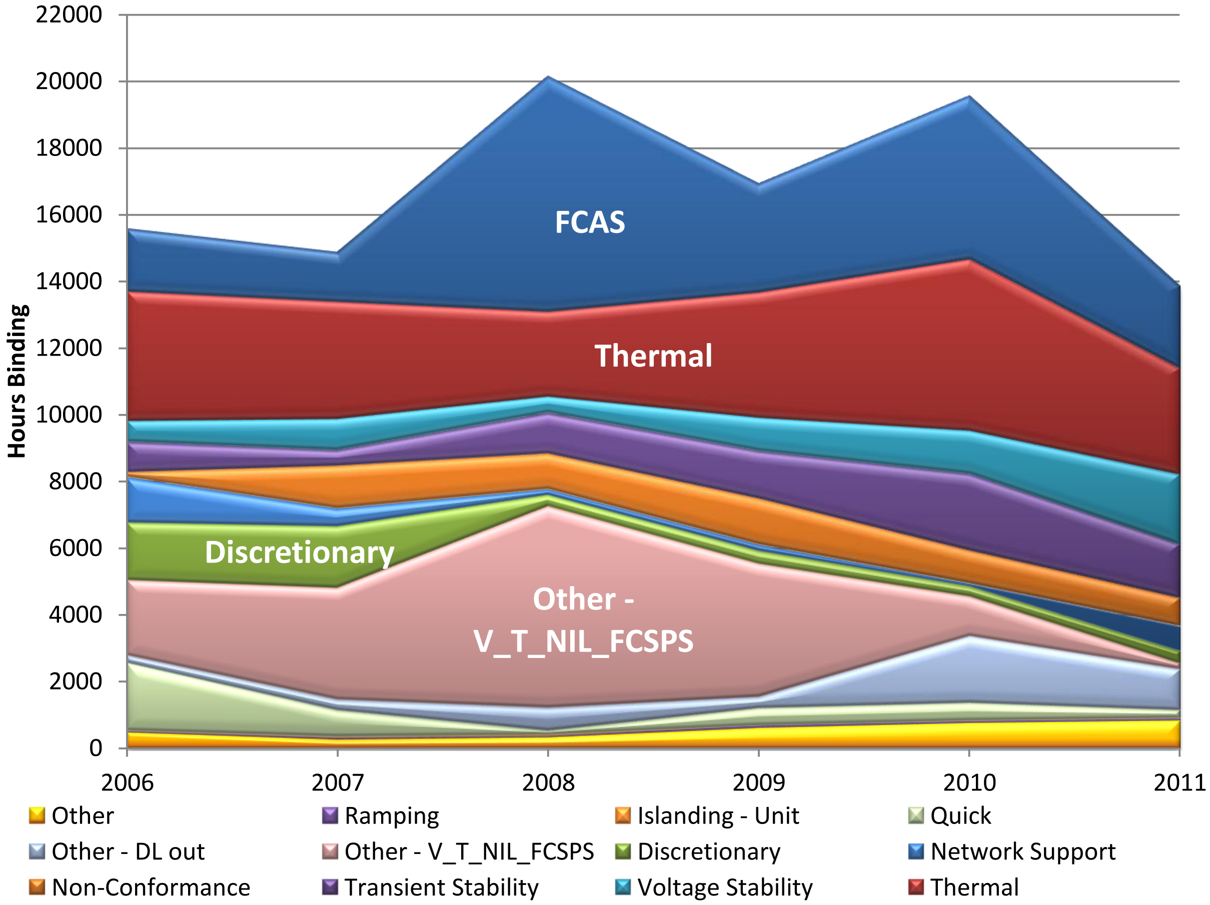

Figure 7: Binding constraint equations by limit type

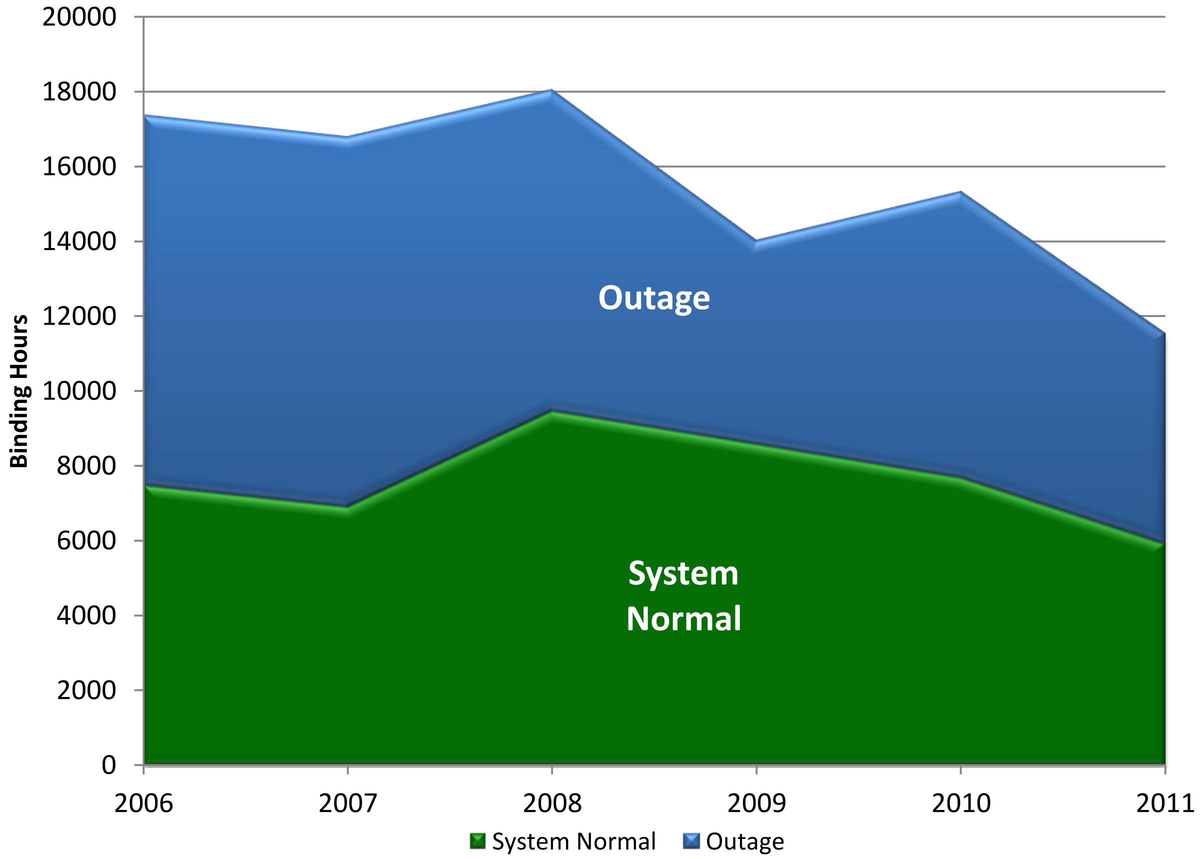

Figure 8: Binding hours for system normal and outages

7.2 Violating constraint equations

A constraint equation is violating when NEMDE is unable to dispatch the entities on the LHS so the summated LHS value is less than or greater than the RHS value (depending on the mathematical operator selected for the constraint equation).

Table 5: Top 20 violating constraint equations

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
NSA_Q_GSTONE34_450	10 (0)	*Gladstone 3 + 4 >= 450 for Network Support Agreement* The constraint violated for 93 consecutive DIs in August 2011 and a number of other times in July and November. In August the constraint equation violated after Gladstone 4 was unable to maintain its output. Powerlink conducted studies and concluded that the issue was not causing an insecure situation. Contingency analysis was monitored throughout the period by both AEMO and Powerlink and the outage would have been recalled if necessary. The maximum violation was 60 MW. At other times the violations were due to either reduced availability of the Gladstone units or the units performing a backflush.
S>SETX_SETX_SGKH	8 (0)	*Out = one South East 275/132 kV transformer, avoid overload on Snuggery to Keith 132 kV line on trip of the other South East 275/132 kV transformer* This constraint equation violated for 91 DIs on 4 and 5 July 2011 with a max violation of 61.88 MW. The violations were intermittent and lasted for no more than 5 consecutive dispatch intervals. During this time no RTCA violations were noted. In most cases, Lake Bonney 3 was slightly above the market target. The constraint equation has since been retuned.
#VIC1-NSW1_E_E	6 (6.5)	*Quick constraint equation applied to VIC1-NSW1 at various levels* This quick constraint equation was invoked to manage negative residues. Most of the violations occurred on 30 and 31 May 2011. Constraint equations used to manage negative residues have lower constraint violation penalty (CVP) factors than network constraints (that is less than 20). The negative residue constraint equations therefore will violate before the network constraint equations. Such violations do not indicate a security issue unlike other constraint equations.
F_T+NIL_TL_L6	4 (0.8)	*Tasmania lower 6 second requirement for loss of 2 Comalco potlines, Basslink unable to transfer FCAS* This constraint equation violated on a number of occasions in 2011. In April and December the violation was due to insufficient availability of lower 6 second services in Tasmania. In June and August the violations were due to Basslink being in, close to or transitioning through it's no go zone. In July the violation was caused by an issue with the AEMO application that sends targets to Basslink (which has been found and rectified).
N>N-NIL_TE_E1	3 (1.3)	*Out = Nil, avoid overloading Armidale to Coffs Harbour (96C) 132 kV line on trip of Armidale to Coffs Harbour (87) 330 kV line* On 2 February 2011 this constraint equation violated when it tried to set a lower Qld to NSW limit than Q>NIL_757+758_B. As Q>NIL_757+758_B has a higher CVP N>N-NIL_TE_E1 violated for 29 dispatch intervals. During this time TransGrid enabled Armidale overload protection scheme. The overload protection scheme installed at Armidale is designed to protect lines Armidale to Kempsey (965), Armidale to Koolkhan (966), Armidale to Coffs Harbour (96C) and Armidale to Glen Innes (96T) 132 kV lines in the event that their loadings exceed their respective 5-minute ratings following a line trip contingency.
N_X_MBTE2_B	2	*Out = two Directlink cables, Queensland to NSW limit*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
	(2.7)	This constraint equation violated due to a ramping constraint equation for the outage of the Koolkhan to Lismore (967) 132 kV in May and June. The violations persisted until the ramping target was met. Also see Table 3 for comments.
NSA_V_BDL01_20	2 (1.2)	*Bairnsdale Unit 1 >= 20 MW for network support agreement* In May the constraint equation violated as the incorrect Bairnsdale unit was started. In July the violations were resolved when a rebid was received.
NSA_Q_GSTONE34_410	2 (0)	*Gladstone 3 + 4 >= 410 for Network Support Agreement* Constraint equation violated on multiple occasions in October and November 2011. On 31 October it violated for 6 consecutive 6 DIs (with a max violation of 95.03 MW) due to Gladstone unit 4 being trapped by FCAS. On 10 November 2011 the constraint equation violated for 5 DIs due to Gladstone units 3 and 4 back flushing.
N>N-KKLS_TE_2	2 (0)	*Out = Koolkhan to Lismore (967) 132 kV line, avoid overloading the Armidale to Glen Innes (96T) 132 kV line on trip of Coffs Harbour to Lismore (89) 330 kV line* This constraint equation violated with a concurrent outage of 2 Directlink cables. TransGrid provided temporary ratings for the Armidale to Glen Innes (96T), Glen Innes to Tenterfield (96R) and Tenterfield to Lismore (96L) 132 kV lines for the duration of the outage. There was also the option to radialise the network by opening the 96L line but was not taken. Max violation of 19.23736 MW
F_T+LREG_0050	2 (0)	*Tasmania lower regulation requirement greater than 50 MW, Basslink unable to transfer FCAS* A number of violations occurred across 2011 and these were mainly due to SCADA failure. In one case in Feb 2011 the violation was due to insufficient lower regulation services bid available.
F_T+RREG_0050	2 (0)	*Tasmania raise regulation requirement greater than 50 MW, Basslink unable to transfer FCAS* A number of violations occurred across 2011 and these were mainly due to SCADA failure. In one case in Feb 2011 the violation was due to one of the larger Tasmanian generators being stranded resulting in insufficient raise regulation services.
NSA_Q_GSTONE34_370	2 (0)	*Gladstone 3 + 4 >= 370 for Network Support Agreement* The constraint equation violated for several DIs on 22 November and for 10 consecutive DIs on 25 November. The power system was assessed to be secure during both periods. The violations were due to Gladstone unit 3 carrying out a backflush and Gladstone unit 4 being limited by its ramp rate.
N>N-CHKK_TE_1	2 (0)	*Out = Coffs Harbour to Koolkhan (96H) 132 kV line, avoid overloading Armidale to Koolkhan (966) 132 kV line on trip of Coffs Harbour to Lismore (89) 330 kV line* This constraint equation violated during the concurrent outage of Armidale to Tamworth (85) 330 kV line and 96H line. Interaction with the binding Terranora interconnector rate of change constraint equation QNTE_ROC resulted in oscillating flows on NSW1-QLD1 and Terranora Interconnectors.
F_S++HYML_L60	1 (0)	*Out = one Heywood to Moorabool 500 kV line or one Moorabool to Sydenham 500 kV line, SA lower 60 sec requirement* Constraint equation violated for 13 DIs on 04 Oct 2011 from 10:15 hrs. Max violation of 30.56 MW. The violation occurred during Mortlake

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		commissioning and a planned outage of Alcoa Portland to Heywood No.2 500 kV line and Heywood to Mortlake No.2 500 kV line (which also offloaded Heywood 500/275 kV (M2) transformer). There were insufficient lower services in SA to cover the loss of remaining Heywood 500/275 kV transformer, which would result in SA being islanded. Commissioning of Mortlake was postponed.
S>VML_NWCB6023_TX2	1 (0)	*Out = North West Bend CB6023, avoid overloading North West Bend #2 132/66 kV transformer on trip of North West Bend to Robertstown 132 kV line* Constraint equation violated for 11 consecutive DIs on 25/12/2011 from 20:35 hrs with a maximum violation of 16.18 MW. Murraylink, the North West Bend to Monash #2 132 kV line and the Monash to Berri #2 132kV line all tripped at 2013 hrs. Murraylink was constrained to zero. S>VML_NWCB6023_TX2 only has Murraylink on the LHS and it was blocked from 21:30 hrs. ElectraNet confirmed that there was no security issue due to the over current protection available for the North West Bend No. 2 transformer.
CA_SPS_3CACE072_01	1 (0)	*Constraint Automation, avoid overloading Ballarat to Waubra 220 kV line for trip of the Ballarat to Bendigo 220 kV line* This constraint equation was created on 5 April 2011 due to RTCA indicating an issue on the Ballarat to Waubra 220 kV line during a concurrent outage of the Darlington Point to Wagga (63) 330 kV line and Ballarat to Shepparton 220 kV line. CA_SPS_3CACE072_01 only had Murraylink export to Victoria on the LHS and Murraylink was being constrained by S>>V_NIL_RBTX2_RBTX1 (avoid overloading a Robertstown 275/132 kV transformer). There were instances where the target for Murraylink caused this constraint equation to violate.
NC_V_BDL01	1 (0.8)	*Non Conformance Constraint for Bairnsdale 1 Power Station* This constraint equation violated for a few dispatch intervals while the unit ramped up to target (May 2011) or was unavailable for its network support agreement (January 2011).
NSA_Q_GSTONE34_430	1 (0)	*Gladstone 3 + 4 >= 430 for Network Support Agreement* The constraint violated for 8 non-consecutive DIs with a max violation of 12.98 MW. The condenser at Gladstone was being back flushed during this time.
#N-Q-MNSP1_I_E	1 (0.5)	*Quick constraint equation applied to Terranora Interconnector at various levels* On 3 February this quick constraint equation was invoked to manage oscillations due to non-physical loss runs on Terranora interconnector. As the constraint equation had a low CVP (0.0001) it violated before network constraint equations with CVPs of 20. Such violations do not indicate a security issue unlike other constraint equations. On 29 March this quick constraint equation was invoked to manage Directlink flows due to a communications outage between AEMO and Directlink.
T_T_FASH_3_N-2	1 (0)	*Out = Nil, loss of both Farrell to Sheffield 220 kV lines declared credible, Farrell 220 kV bus split, Hampshire link open, constrain Reece Unit 1 to 0 MW as per Transend advice* In September 2011 this constraint equation violated due to Tasmanian FCAS requirements not being met.

8 Market impact of constraint equations

Constraint equations can be compared using their market impact. The market impact is determined by summating the marginal values from the marginal constraint cost (MCC) re-run. This re-run removes any violating constraint equations as well as relaxing (slightly) any constraint equations with a marginal value equal to the constraint equation's CVP x market price cap (MPC) (for example 200000 or 3600000). For the purposes of the calculation the marginal value in each dispatch interval is capped at the MPC valid on that date (MPC was increased to $12,500 on 1st July 2010).

Similar to the binding and violating constraint equations tables in the previous section Table 6 indicates system normal constraint equations in bold and the number of binding hours for 2010 is indicated in brackets below the 2011 hours. The 2010 summated marginal values are indicated in brackets below the 2011 hours.

The constraint equations NSA_Q_BARCALDN, NSA_Q_GSTONE34_xxx, Q<QBCG_02, NSA_V_BDL0xxx, S_PLN_ISL32 and S_PLN_ISL32 are all for the output of a one or two generators equal to or greater than or equal to the RHS. These are either for network support from a generator or an outage of the radial transmission line connecting to the unit. While it appears they have a large market impact, this is more due to the bidding of the individual generator.

Table 6: Top 20 market impact constraint equations in 2011

EQUATION ID (SYSTEM NORMAL BOLD)	Σ MARGINAL VALUES	HOURS (2010)	*DESCRIPTION* / NOTES
NSA_Q_BARCALDN	$3,677,819 (0)	25.3 (0)	*Network Support Agreement for Barcaldine GT to meet local islanded demand at Clermont and Barcaldine for the outage of Clermont to Lilyvale (7153) 132 kV line* This constraint equation was newly created in August 2011 to manage the new network support agreement for Barcaldine islanded from the rest of Queensland. In future it will be used for planned outages.
NSA_Q_GSTONE34_xxx	$2,962,336 ($1,969)	693.8 (34.9)	*Gladstone 3 + 4 >= various levels for Network Support Agreement* See Table 3 for comments
Q<QBCG_02	$2,427,766 (0)	20.4 (0)	*Out = Barcaldine to Clermont (7154) 132 kV line, Barcaldine power station islanded* Prior to August 2011 this constraint equation was used for outages of the 7154 line and for planned outages has been replaced with NSA_Q_BARCALDN (see above). This constraint equation was relabelled in early 2012. The new constraint equation Q_BARCALDN_ISL will be used for unplanned outages.
NSA_V_BDL0xxx	$811,280 ($70)	6.3 (0.1)	*Bairnsdale Unit 1 or 2 >= various levels for Network Support Agreement* The binding results from 4 constraint equations that set the minimum level of Bairnsdale 1 or 2 generation have been combined. These constraint equations were invoked for a total of 29.8 days in 2011 and 8.3 days in 2010.
N>>N-NIL_5MRAS_B_15M	$678,075 (0)	15.3 (0)	*Out = Snowy 5MRAS scheme, avoid overloading Upper Tumut to Canberra (1) 330 kV line on trip of Lower Tumut to Canberra (7) 330 kV line* This constraint equation bound in Jan/Feb 2011 for high flows from Victoria to NSW.
F_S++HYML_L60	$585,389 ($516,002)	137.1 (72.3)	*Out = one Heywood to Moorabool 500 kV line or one Moorabool to Sydenham 500 kV line, SA lower 60 sec requirement*

			The Heywood to Moorabool lines were out for a total of 11 days in 2011 compared to 27.3 days in 2010 - see Table 19.
V>>S_NIL_SETB_KHTB	$544,809 ($129)	17.7 (0.8)	*Out = Nil, avoid overloading Keith to Tailem Bend #1 132 kV line for trip of South East to Tailem Bend 275 kV line*
V_HYMO2_1	$499,601 (0)	3.8 (0)	*Out = Heywood to Mortlake No. 2 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service* This constraint equation was new in 2011 and was introduced with the commissioning of the Mortlake substation and power station.
V^SML_NSWRB_2	$480,721 ($490,102)	15.1 (25.3)	*Out = NSW Murraylink runback scheme, avoid voltage collapse for trip of Darlington Point to Buronga (X5) 220 kV line* This constraint equation is currently part of the Victorian system normal constraint set, as the NSW Murraylink runback scheme has not been commissioned.
S>V_NIL_NIL_RBNW	$478,247 ($142,325)	175.3 (141.0)	*Out = Nil, avoid overloading the North West Bend to Robertstown 132 kV line on no line trips* See Table 3 for comments
S_PLN_ISL32	$383,260 ($795)	3.4 (4.1)	*Out = Yadnarie to Port Lincoln 132 kV line, Port Lincoln unit #3 islanded* This line was out for a short period on 22 Feb 2011.
V>>SML_NIL_7A	$362,910 ($18,776)	21.8 (8.8)	*Out = Nil, avoid overloading Ballarat North to Buangor 66 kV line on trip of the Ballarat to Waubra to Horsham 220 kV line*
V^^S_NIL_NPS_xxx & V^^S_TBCP_NPS_xxx & V^^S_NIL_MAXG_xxx	$286,103 ($554,702)	1,120.7 (576.6)	*Out = Nil, Victoria to SA long term voltage stability limit for loss of the largest credible generation contingency in SA, South East capacitor bank on / off, Tailem Bend capacitor bank on/off* See Table 3 for comments
F_T+NIL_BL_R6_1 & F_T++NIL_BL_R6_x	$283,827 ($925,299)	2,801.2 (3,963.3)	*Tasmania raise 6 second requirement for loss of Basslink, FCSPS available* See Table 4 for comments
Q>>X_809_8818_832_1	$206,930 (0)	65.0 (0)	*Out = Rocklea to South Pine (809) and Tarong to South Pine (832) 275 kV lines, avoid overloading Blackwall to South Pine (838) 275 kV line on trip of Mt England to South Pine (825) 275 kV line* These constraint equations were constructed for the multiple outage case following the Queensland floods in January 2011 and the binding results have been combined. Q>>X_809_8818_832_1 including the outage of the Blackwall to Rocklea (8818) 275 kV line, however there are only minor factor changes between it and Q>>X_809_832_1.
S>>V_NIL_RBTX2_RBTX1	$188,517 (0)	16.3 (0)	*Out = Nil, avoid overloading Robertstown #1 275/132 kV transformer on trip of Robertstown #2 275/132 kV transformer* This constraint equation was removed from the South Australian system normal based on advice in August 2011 on the Waterloo wind farm run back scheme.
CA_SPS_3CACE072_01	$180,607 (0)	7.2 (0)	*Constraint Automation, avoid overloading Ballarat to Waubra 220 kV line for trip of the Ballarat to Bendigo 220 kV line*

			See Table 5 for comments
F_I+NIL_MG_R5	$159,816 ($92,018)	8,063.0 (7,944.5)	*NEM raise 5 minute requirement for a NEM generation event* See Table 4 for comments
Q:N_NIL_BCK2L-G	$158,605 ($34,596)	38.0 (614.5)	*Out = Nil, avoid transient instability for a 2 phase to ground fault on a Bulli Creek to Dumaresq line at Bulli Creek* For high flows from Queensland to NSW either this constraint equation or Q:N_NIL_BI_POT or Q:N_NIL_OSC will bind.
S_PLN_ISL2	$156,568 ($536,971)	3.4 (4.2)	*Out = Yadnarie to Port Lincoln 132 kV line, Port Lincoln units 1 and 2 islanded* This line was out for a short period on 22 Feb 2011.

8.1 Market impact trends

In this section the trends on market impact are examined. As the MCC data is only available from July 2008 onwards only the calendar years 2009 to 2011 are examined. The trend over the past 3 years is the market impact is reducing and this is primarily due to the reduced market impact from the system normal constraint equations (see Figure 11).

Most regions have reduced their market impact in the past 3 years (see Figure 9) with the exception of Queensland. The market impact increase in Queensland can be attributed to the high market impact of network support constraint equations (see Table 6 and Figure 10). Compare the trend in Figure 9 with the binding hours in Figure 6 where there is no overall trend and some regions increased binding hours whereas others decreased.

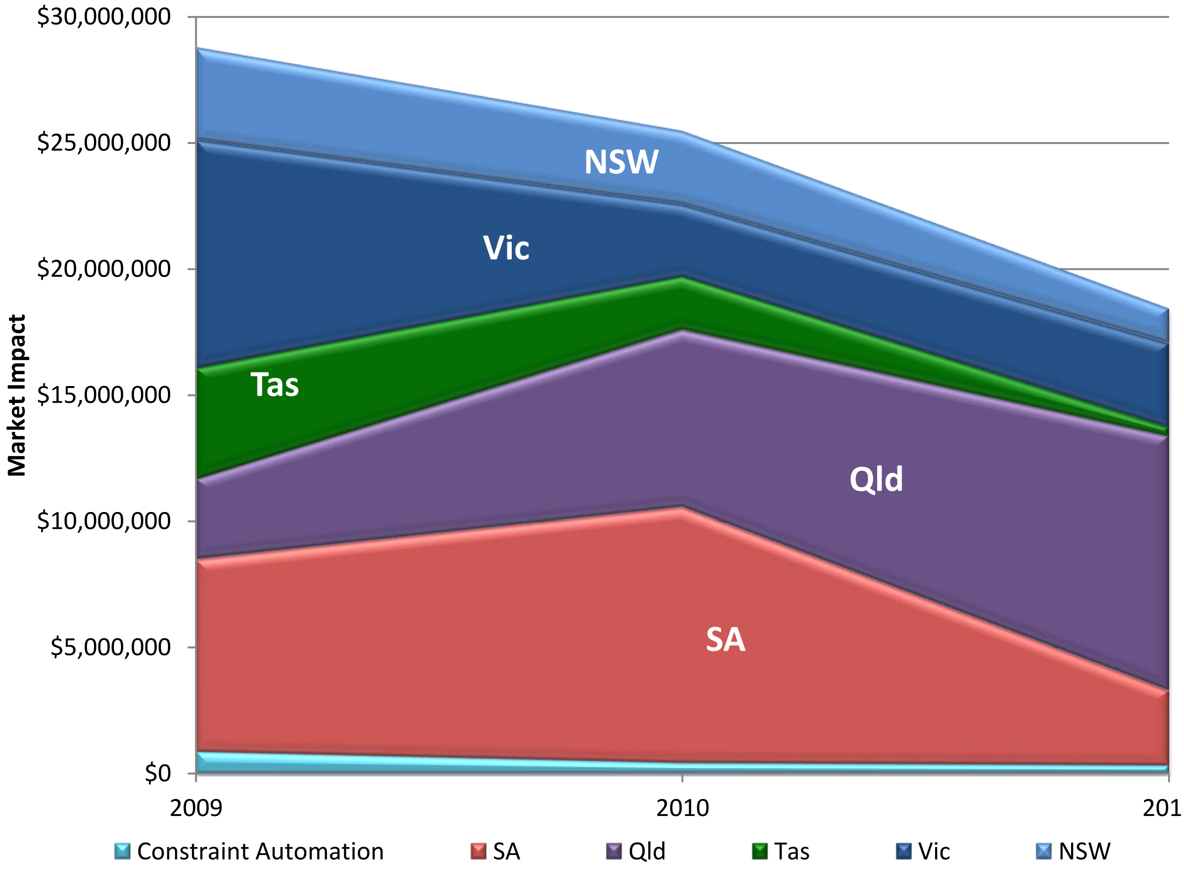

Figure 9: Market impact by region

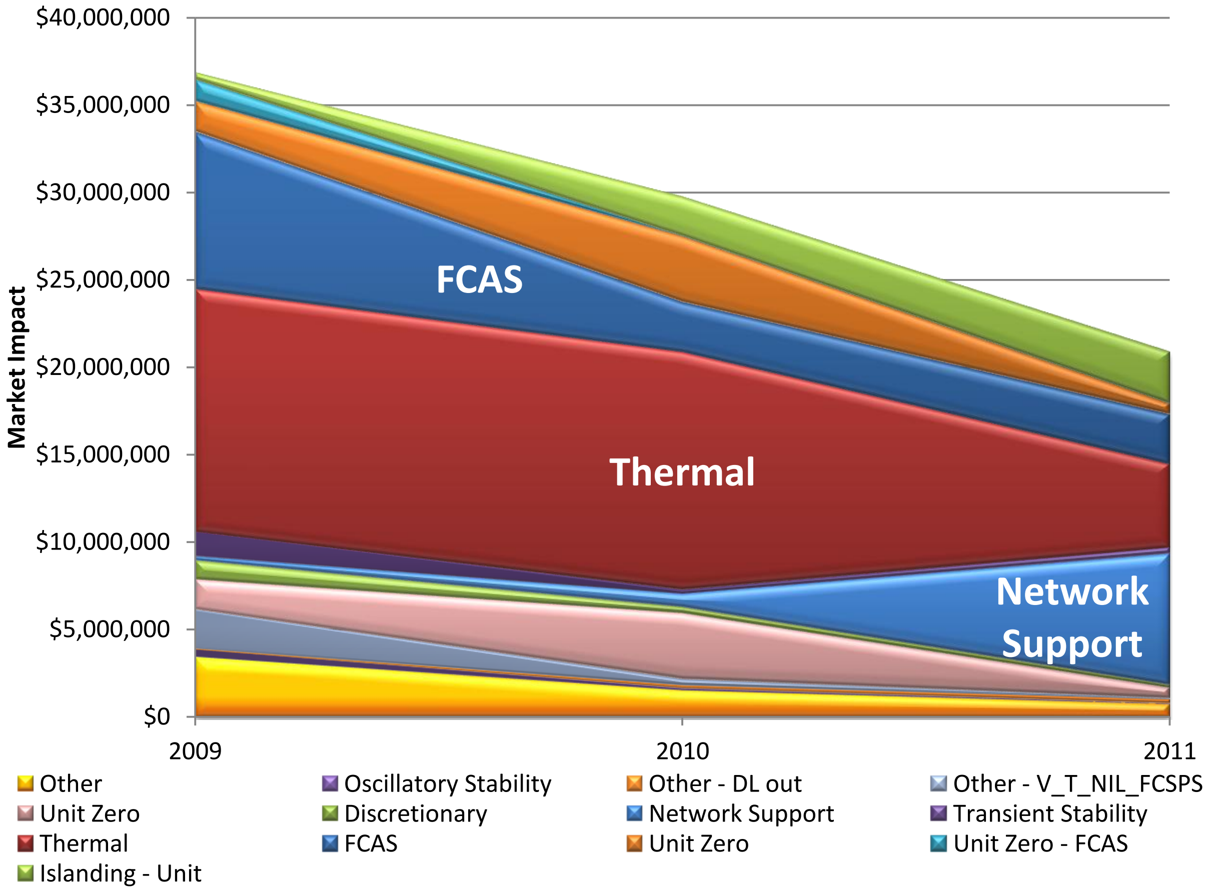

Figure 10: Market impact by constraint equation limit type

Comparing the market impact by the limit type of the constraint equation (see Figure 10) again shows an overall decrease in market impact with the exception of network support and islanding constraint equations. Contrast this with the binding hours per limit type (Figure 7) where FCAS binds for a large number of hours and network support has a low number of binding hours.

Note the FCAS in Figure 10 includes the impact due to system normal FCAS constraint equations whereas this is excluded from Figure 7.

The market impact of outages to system normal is compared in Figure 11 and this graph indicates that while the impact of outages has increased since 2009 the impact due to system normal constraint equations has decreased at a greater rate. This reduction in market impact of system normal constraint equations has led to the overall reduction in market impact since 2009. There has been (since 2009) a slight reduction in binding system normal hours (see Figure 8), however, there has been a fall in the number of hours of outage binding hours. The outage binding hours have been below the system normal hours since 2008.

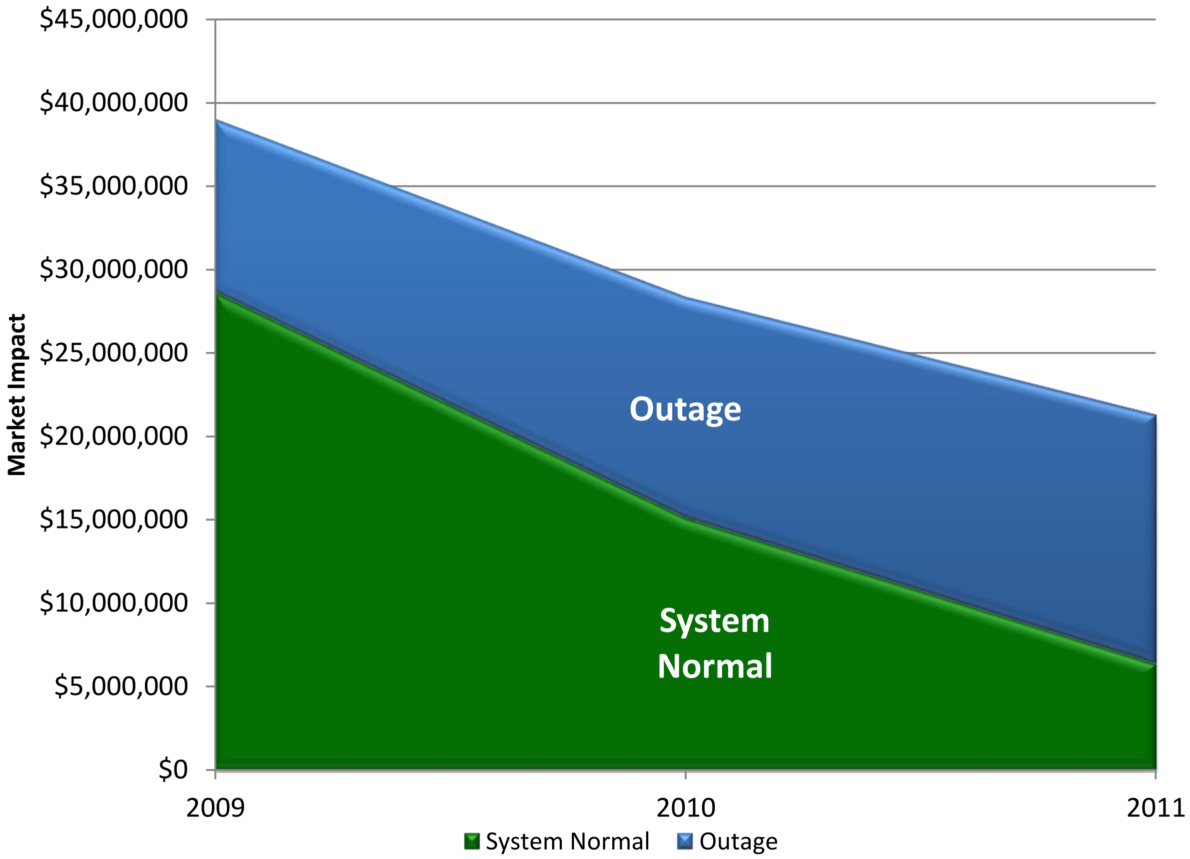

Figure 11: Market impact for system normal and outages

9 Constraint equations setting interconnector limits

Constraint equations with an interconnector on the LHS can set the reported limits on the interconnector. This section examines each of the interconnectors in the NEM and the binding constraint equations that most often set the interconnector limits. For each interconnector there is a graph of the monthly binding hours, a histogram of the flows at which constraint equations bound and tables of the top 10 binding interconnector limit setters in each direction.

As only one constraint equation can be reported as setting the import or export limit for an interconnector at a particular time, the binding hours will differ from section 7 when two (or more) constraint equations could set the limit. In these cases when calculating the interconnector limit AEMO's market systems software selects a constraint equation based on the following priority order:

1) Single interconnector on the LHS
2) Multiple interconnectors and generators (energy) on the LHS
3) Multiple interconnectors, FCAS requirements and generators (FCAS) on the LHS

The monthly graphs in this section show the binding hours per month for each direction on each interconnector. The results exclude the outage ramping constraint equations. The export binding hours are indicated as positive numbers and import with negative values. Each month is further categorized into 5 types:

- System normal
- Outage
- FCAS: This includes all constraint equations that start with "F" even those which are in the FCAS system normal set

- Constraint automation: All the constraint equations created by the constraint automation application
- Quick: constraint equations created by AEMO's control room staff. These all start with "#" and exclude the outage ramping constraint equations.

The histograms in this section show the flows for the top 5 (for each direction of flow) binding interconnector limit setting constraint equations. The remaining binding interconnector limit setting constraint equations are summated as “Other”. For comparison the summated binding hours for the previous year is included on the primary axis and on the secondary axis is the number of hours the interconnector target was at each flow level (binding or not binding) for the current and past calendar year.

Note that in cases where the constraint equations setting the import and export limits on an interconnector are both binding, then both constraint equations are counted in the results.

9.1 Terranora interconnector (N-Q-MNSP1)

The Terranora interconnector comprises the two 110 kV lines from Terranora in NSW to Mudgeeraba in Queensland. However, the controllable element is a 180 MW DC link between Terranora and Mullumbimby known as Directlink, which consists of 3 separate DC lines. The DC lines were commissioned in 2000 forming the first connection between NSW and Queensland. Normally flows on this interconnector are towards NSW and so both the import and export values are negative (unlike the other interconnectors in the NEM). It is usually constrained by thermal limits in northern NSW or rate of change on Directlink. However, it often appears on the LHS of constraint equations with the Queensland to NSW interconnector so both may be constrained at the same time.

A number of the thermal constraint equations (such as N>N-NIL_TE_E1, N^N-KKLS_1 and N>N-KKLS_TE_2) should be relieved with the construction of the Dumaresq to Lismore 330kV line in 2015[7]. In 2011 the majority of the flow on Terranora is restricted by outages of two or more Directlink cables as well as outages of the Armidale to Tamworth 330 kV lines (see Figure 13).

The hours at each flow level on Terranora were very similar in 2010 and 2011 and the binding hours are similar except there were more flows and binding hours for flows from -200 to -120 MWs (see Figure 13).

[7] http://www.transgrid.com.au/projects/projects/dumaresq_lismore/Pages/default.aspx

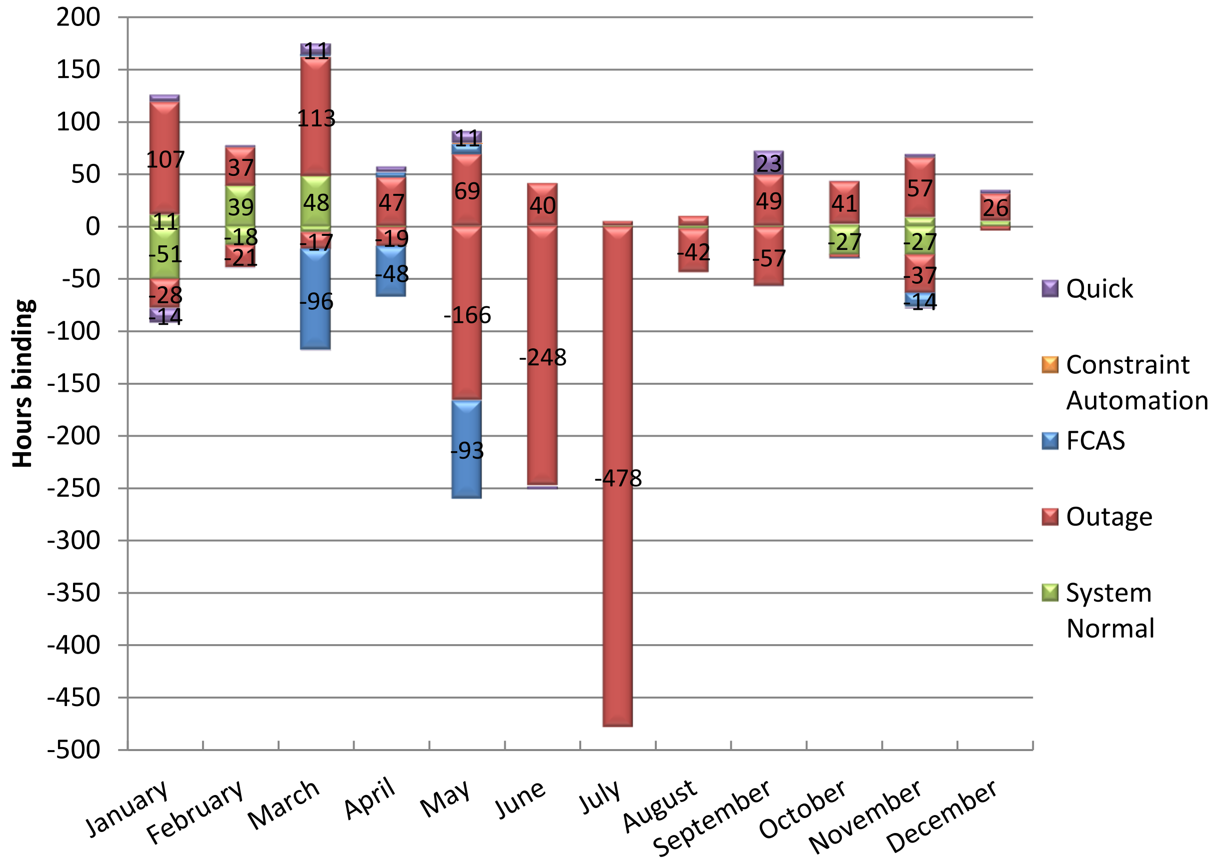

Figure 12: Categorized binding intervals per month for N-Q-MNSP1

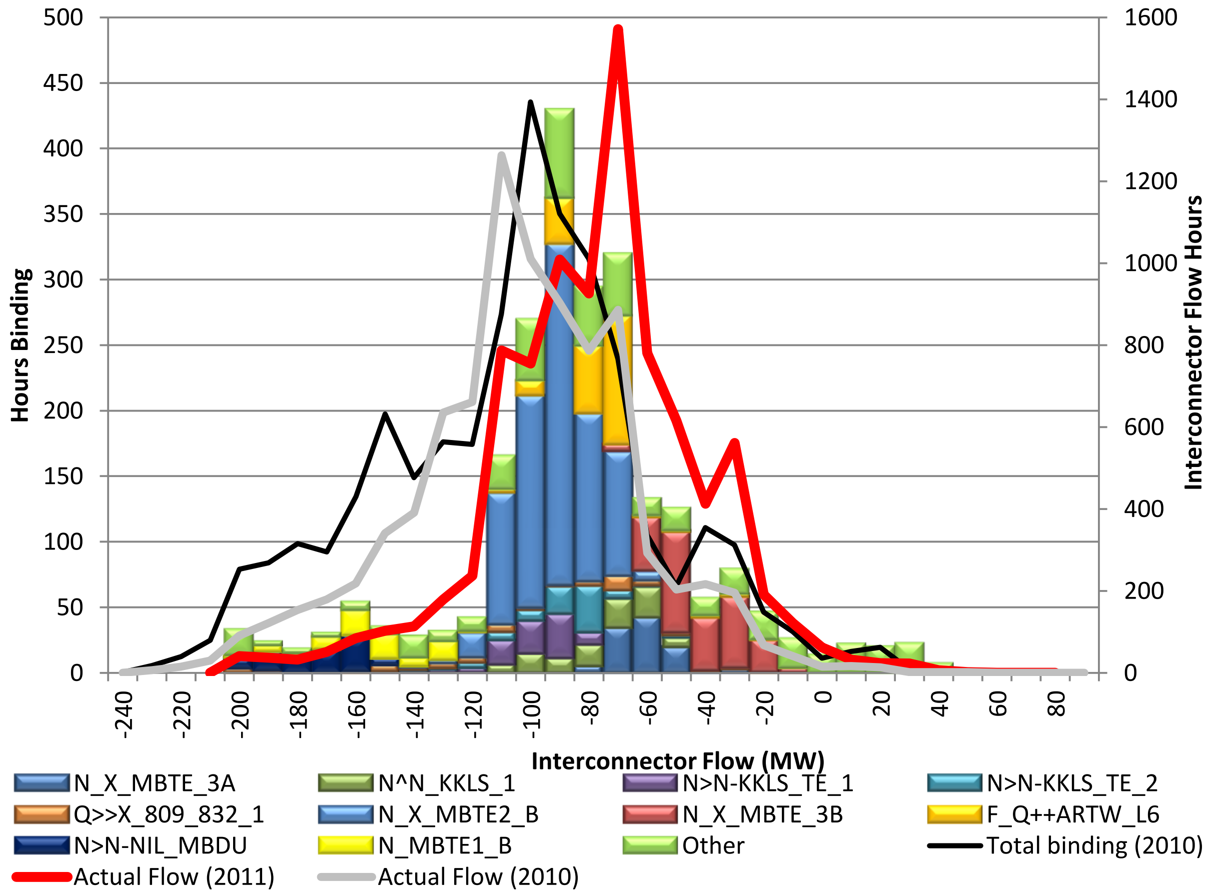

Figure 13: Binding constraint equation distribution for N-Q-MNSP1

Table 7: Binding constraint equations setting the NSW to Qld limit on N-Q-MNSP1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
N_X_MBTE_3A	104.3 (30.6)	*Out = all three Directlink cables, NSW to Queensland limit* See Table 3 for comments
N^N_KKLS_1	101.8 (0)	*Out = Koolkhan to Lismore (967) 132 kV line, avoid voltage collapse on trip of Coffs Harbour to Lismore (89) 330 kV line* See Table 3 for comments
N>N-KKLS_TE_1	95.4 (173.5)	*Out = Koolkhan to Lismore (967) 132 kV line, avoid overloading Tenterfield to Lismore (96L) 132 kV line on trip of Coffs Harbour to Lismore (89) 330 kV line* See N^N_KKLS_1 in Table 3 for comments
N>N-KKLS_TE_2	84.4 (0)	*Out = Koolkhan to Lismore (967) 132 kV line, avoid overloading the Armidale to Glen Innes (96T) 132 kV line on trip of Coffs Harbour to Lismore (89) 330 kV line* See N^N_KKLS_1 in Table 3 for comments
Q>>X_809_8818_832_1 & Q>>X_809_832_1	64.4 (0)	*Out = Rocklea to South Pine (809) and Tarong to South Pine (832) 275 kV lines, avoid overloading Blackwall to South Pine (838) 275 kV line on trip of Mt England to South Pine (825) 275 kV line* See Table 6 for comments
#N-Q-MNSP1_I_E	58.0 (12.2)	*Quick constraint equation applied to Terranora Interconnector at various levels* This quick constraint equation was invoked a number of times during 2011 to manage power system security when the Directlink was unable to be controlled (due to a communication failure) and oscillations in dispatch targets across successive dispatch intervals.
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	51.8 (35.2)	*Out = Nil, avoid voltage collapse for loss of the largest Queensland generator* This voltage collapse limit is split into 7 constraint equations to co-optimise with each of the 6 largest generators in Queensland. Overall N^^Q_NIL_B1 (for trip of Kogan Creek) binds for the most number of intervals.
N_X_MBTE2_A	25.7 (39.4)	*Out = two Directlink cables, NSW to Queensland limit* See Table 3 for comments
N>N-NIL_TE_E1	25.4 (22.3)	*Out = Nil, avoid overloading Armidale to Coffs Harbour (96C) 132 kV line on trip of Armidale to Coffs Harbour (87) 330 kV line* The binding hours for this constraint equation would normally be higher. The low value is due to the number of outages of the 132 kV lines between Armidale and Lismore (in particular outages of 967 line) in 2010 and 2011 and the outage constraint equations binding instead.
N>N-NIL_LSDU	22.8 (5.4)	*Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) 132 kV line on trip of the other Lismore to Dunoon line (9U7 or 9U6) 132 kV line* This constraint equation only binds when all three Directlink cables are in service.

Table 8: Binding constraint equations setting the Qld to NSW limit on N-Q-MNSP1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
N_X_MBTE2_B	770.9	*Out = two Directlink cables, Queensland to NSW limit*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
	(1117.8)	See Table 3 for comments
N_X_MBTE_3B	244.9 (307.3)	*Out = all three Directlink cables, Queensland to NSW limit* See Table 3 for comments
F_Q++ARTW_L6	205.6 (55.3)	*Out = Armidale to Tamworth (85 or 86) 330 kV line, Queensland lower 6 second FCAS requirement* The Armidale to Tamworth lines (either 85 or 86) were out for a total of 24.3 days in 2011 (compared to 4 days in 2010). See Table 19.
N>N-NIL_MBDU	84.7 (206.9)	*Out = Nil, avoid overloading Mullumbimby to Dunoon (9U6 or 9U7) 132 kV line on trip of the other Mullumbimby to Dunoon (9U7 or 9U6) 132 kV line* This constraint equation only binds when all three Directlink cables are in service.
N_MBTE1_B	73.8 (477.0)	*Out = one Directlink cable, Queensland to NSW limit* One of the three Directlink cables was out for a significant part of 2011 (194.3 days) and 2010 (243 days). See Table 19.
F_Q++ARTW_L5	35.3 (19.3)	*Out = Armidale to Tamworth (85 or 86) 330 kV line, Queensland lower 5 minute requirement* See comment on F_Q++ARTW_L6 above
N>N-NIL_DC	21.7 (102.2)	*Out = Nil, avoid overloading Armidale to Tamworth (86) 330 kV line on trip of the other Armidale to Tamworth (85) 330 kV line* This constraint equation bound during January and February 2011 and only in the early hours of the morning (0100 to 0600 hrs).
Q>NIL_MUTE_757 & Q>NIL_MUTE_758 & Q>NIL_757+758_B	18.6 (69.0)	*Out = Nil, avoid overloading a Mudgeeraba to Terranora (757 or 758) 110 kV line on no contingencies* The number of binding hours for these constraint equations is dependent on the Terranora load as well as all 3 cables of Directlink being in service. In May 2011 the constraint equation Q>NIL_757+758_B was replaced with two constraint equations Q>NIL_MUTE_757 and Q>NIL_MUTE_758. The binding results for each have been combined.
#N-Q-MNSP1_RAMP_I_F	10.5 (1.8)	Quick interconnector ramping constraint equation applied to Terranora Interconnector at various levels This constraint equation was used to ramp Terranora to the levels required for the FCAS constraint equations during the outage of an Armidale to Tamworth (85 or 86) 330 kV line.
QNTE_ROC	9.2 (9.8)	*Out = Nil, Rate of Change (Qld to NSW) constraint (80 MW / 5 Min) for Terranora Interconnector*

9.2 Queensland to NSW Interconnector (NSW1-QLD1)

The Queensland to NSW (QNI) interconnector is the AC interconnection between Dumaresq in NSW and Bulli Creek in Queensland. It was commissioned in 2001 as a pair of 330 kV lines between Armidale and Braemar and a pair of 275 kV lines between Braemar and Tarong. The flow is normally from Queensland into NSW. However, at times of high generation in NSW or low generation in Queensland the flow can reverse and go from NSW to Queensland. Due to their close electrical proximity on the NSW side, QNI and Terranora often appear on the LHS of constraint equations.

Transfer from NSW to Queensland is mainly limited by the system normal constraint equations for thermal limits on Calvale to Wurdong (871) line in Queensland and the voltage collapse on loss of the largest Queensland unit (this is dependent on Kogan Creek generation). Transfer from

Queensland to NSW is mainly limited by the oscillatory stability limit and transient stability limits for loss of a Boyne Island potline or fault on a Bulli Creek to Dumaresq line.

In 2010 QNI was heavily constrained when flows were above 950 MW and for the majority of 2010 the flows were greater than 900 MW. In 2011 although the flow was normally from Queensland to NSW the majority of the time flows were between 200 and 750 MW into NSW. Flows between 450 and 550 MW were the most constrained and this was only for 25% of the time (see Figure 15). Note the axes on Figure 15 have been adjusted to the 2011 data as the greater than 950 MW hours in 2010 was much higher (they peaked at 1400 hours) and would dominate the graph.

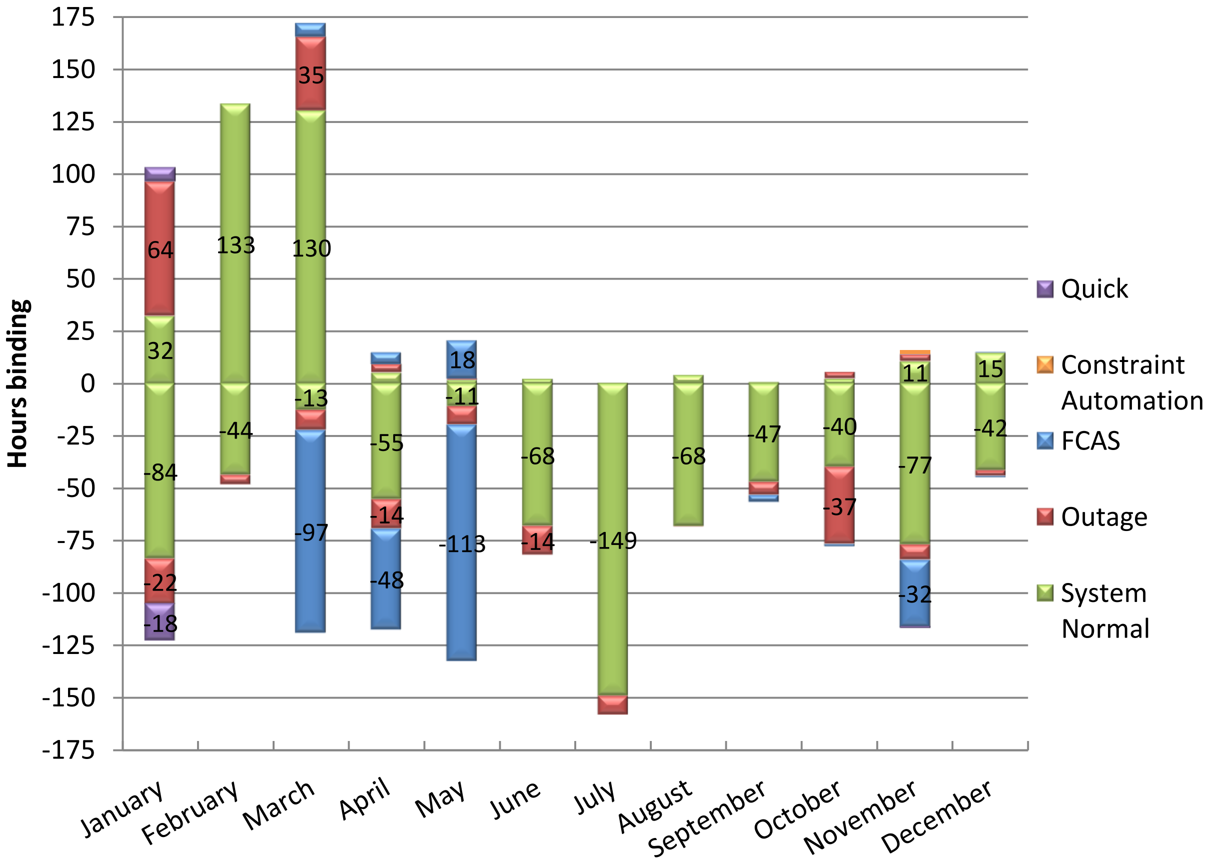

Figure 14: Categorized binding intervals per month for NSW1-QLD1

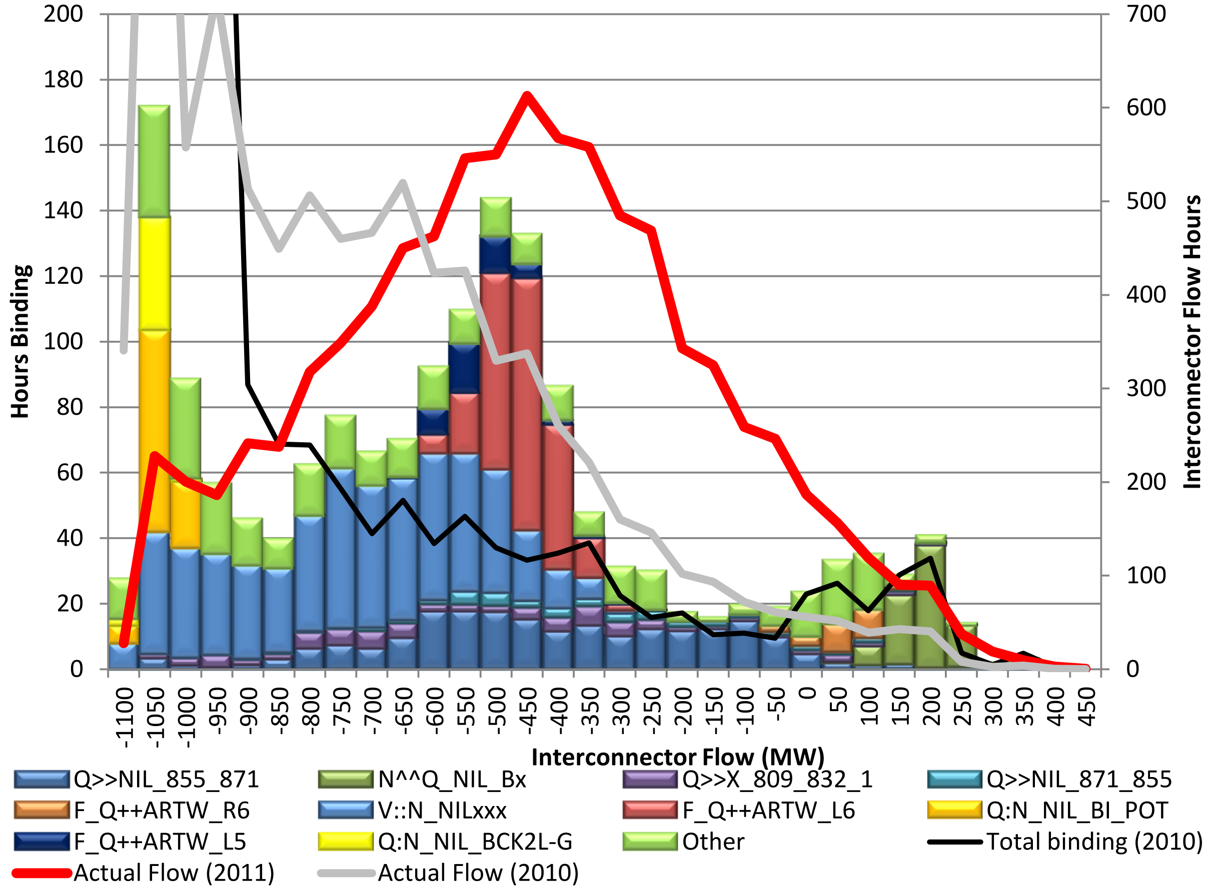

Figure 15: Binding constraint equation distribution for NSW1-QLD1

Table 9: Binding constraint equations setting the NSW to Qld limit on NSW1-QLD1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
Q>>NIL_855_871	215.6 (466.0)	*Out = Nil, avoid overload on Calvale to Wurdong (871) 275 kV line on trip of Calvale to Stanwell (855) 275 kV line* See Table 3 for comments
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	80.3 (60.2)	*Out = Nil, avoid voltage collapse for loss of the largest Queensland generator* See Table 7 for comments
Q>>X_809_8818_832_1 & Q>>X_809_832_1	63.9 (0)	*Out = Rocklea to South Pine (809) and Tarong to South Pine (832) 275 kV lines, avoid overloading Blackwall to South Pine (838) 275 kV line on trip of Mt England to South Pine (825) 275 kV line* See Table 6 for comments
Q>>NIL_871_855	35.3 (3.8)	*Out = Nil, avoid overload on Calvale to Stanwell (855) 275 kV line on trip of Calvale to Wurdong (871) 275 kV line* See comment on Q>>NIL_855_871 in Table 3 for comments
F_Q++ARTW_R6	23.7 (0)	*Out = Armidale to Tamworth (85 or 86) 330 kV line, Queensland raise 6 second FCAS requirement* The Armidale to Tamworth lines (either 85 or 86) were out for a total of 24.3 days in 2011 compared to 4 days in 2010. See Table 19.
N^Q_ARTW_1	16.5 (0)	*Out = Armidale to Tamworth (85 or 86) 330 kV line, avoid voltage collapse on trip of largest Queensland generator*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		See comment on F_Q++ARTW_R6 above
N>N-ARTW86_1B	15.0 (0)	*Out = Armidale to Tamworth (86) 330 kV line, avoid overloading Tamworth to Armidale (85) 330 kV line on trip of largest Queensland generator* See comment on F_Q++ARTW_R6 above
N>>N-NIL_1A	8.5 (0.2)	*Out = Nil, avoid overloading Bayswater to Liddell (33 or 34) 330 kV line on trip of the other Bayswater to Liddell (34 or 33) 330 kV line* This constraint equation bound and set the interconnector limit in January 2011.
#QLD1_E_20110117	6.7 (0)	*Quick constraint equation with both Queensland generators and interconnectors on the LHS applied at various levels* This constraint equation was created to manage the loading on the Blackwall to South Pine (838) 275 kV line on trip of Mt England to South Pine (825) 275 kV line. This was in place until the constraint equation Q>>X_809_8818_832_1 was constructed. Also see Table 6 for comments.
N>N-ARTW_1B	6.0 (0)	*Out = Armidale to Tamworth (85) 330 kV line, avoid overloading Tamworth to Armidale (86) 330 kV line on trip of largest Queensland generator* See comment on F_Q++ARTW_R6 above

Table 10: Binding constraint equations setting the Qld to NSW limit on NSW1-QLD1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
V::N_NILVxxx & V::N_NILQxxx	501.0 (381.4)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 3 for comments
F_Q++ARTW_L6	218.9 (53.6)	*Out = Armidale to Tamworth (85 or 86) 330 kV line, Queensland lower 6 second FCAS requirement* See Table 8 for comments
Q:N_NIL_BI_POT	87.3 (226.3)	*Out = Nil, avoid transient instability for a trip of a Boyne Island potline (400 MW)* See Table 3 for comments
F_Q++ARTW_L5	41.4 (22.8)	*Out = Armidale to Tamworth (85 or 86) 330 kV line, Queensland lower 5 minute requirement* See Table 8 for comments
Q:N_NIL_BCK2L-G	37.5 (599.3)	*Out = Nil, avoid transient instability for a 2 phase to ground fault on a Bulli Creek to Dumaresq 330 kV line at Bulli Creek* See Table 6 for comments
N>N-NIL_DC	30.3 (104.9)	*Out = Nil, avoid overloading Armidale to Tamworth (86) 330 kV line on trip of the other Armidale to Tamworth (85) 330 kV line* See Table 8 for comments
V::N_DDMS_xxx	23.7 (0)	*Out = Dederang to Murray 330 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* There are 12 constraint equations that make up the transient stability export limit from Victoria for this outage and all the binding results have

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		been combined. The Dederang to Murray lines (#1 or #2) were out for a total of 13.3 days in 2011 compared to 0.9 days in 2010 - see Table 19.
Q_N_NIL-1078	23.5 (0)	*Out = Nil, reduce QNI when it is over the 1078 MW limit by 1078 minus the MW over the 1078 MW limit (capped at 1000 MW)* This constraint equation only operates when the NSW1-QLD1 interconnector flow is greater than 1103 MW from Queensland to NSW. It ensures that the interconnector flow does not excessively exceed the 1078 MW limit as a thermal overload limit exists at 1105 MW.
V::N_BUDP_xxx	21.3 (0)	*Out = Buronga to Darlington Point 220 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* There are 12 constraint equations that make up the transient stability export limit from Victoria for this outage and all the binding results have been combined. The Buronga to Darlington Point line was out for a total of 6.8 days in 2011 compared to 0.6 days in 2010 - see Table 19.
Q:N_NIL_OSC	16.3 (271.2)	*Out = Nil, Queensland to NSW oscillatory stability limit* This constraint equation sets the upper limit from Queensland to NSW to 1078 MW. Prior to May 2011 the upper limit set by this constraint equation could be 950 MW if one Millmerran generator was out of service. The 950 MW limit was removed following advice from Powerlink. For high flows from Queensland to NSW either this constraint equation or Q:N_NIL_BI_POT or Q:N_NIL_BCK2L-G will bind.

9.3 Basslink (T-V-MNSP1)

Basslink is a DC interconnection between George Town in Tasmania and Loy Yang in Victoria which was commissioned in early 2006 after Tasmania joined the NEM. Unlike the other DC lines in the NEM, Basslink has a frequency controller and is able to transfer FCAS. Basslink is mainly limited by FCAS or the FCSPS constraint equations. The energy constraint equations that can limit Basslink flow from Victoria to Tasmania are the transient stability limit for a fault and trip of a Hazelwood to South Morang line. Flows from Tasmania to Victoria are mainly limited by the South Morang F2 transformer overload constraint equations.

The flow and binding hours on Basslink were very similar in 2010 and 2011 with the main difference being the lower number of hours of flows at 450 MW from Victoria and Tasmania (see Figure 17).

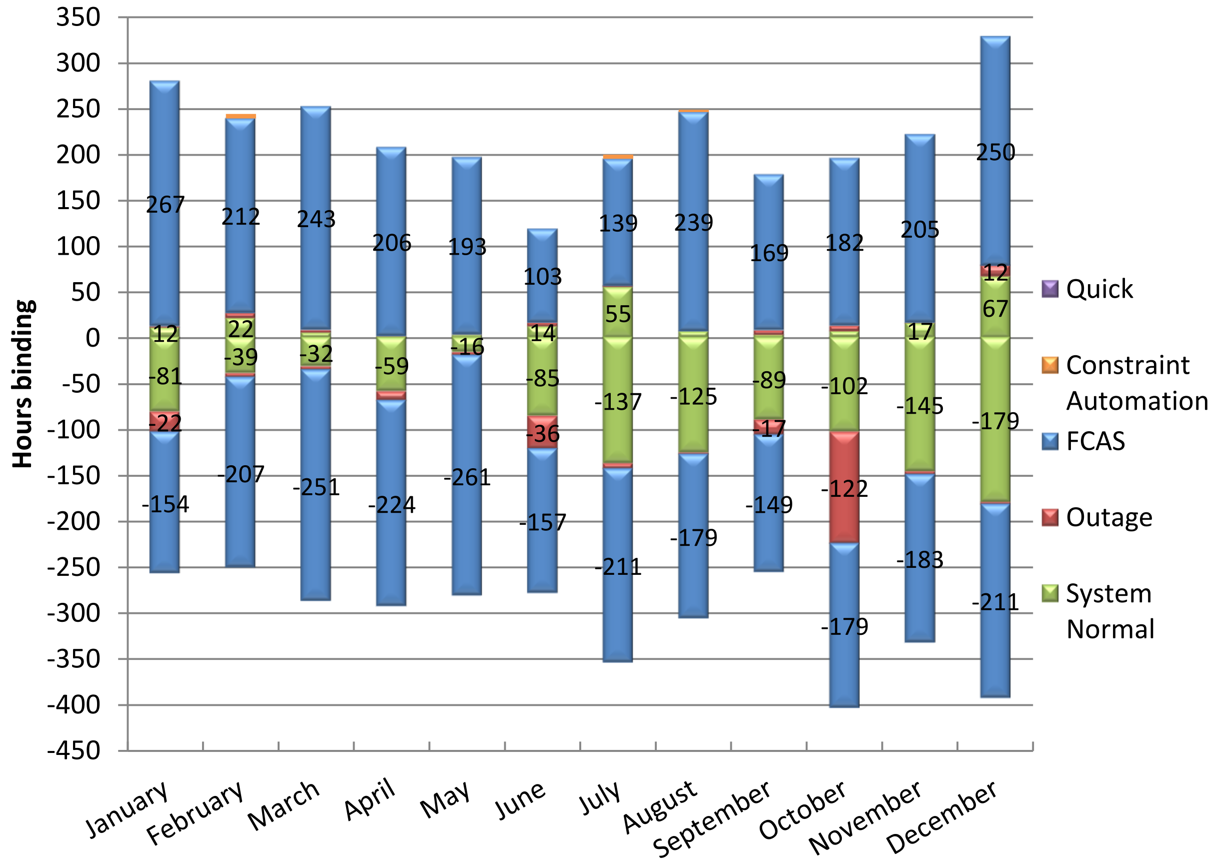

Figure 16: Categorized binding intervals per month for T-V-MNSP1

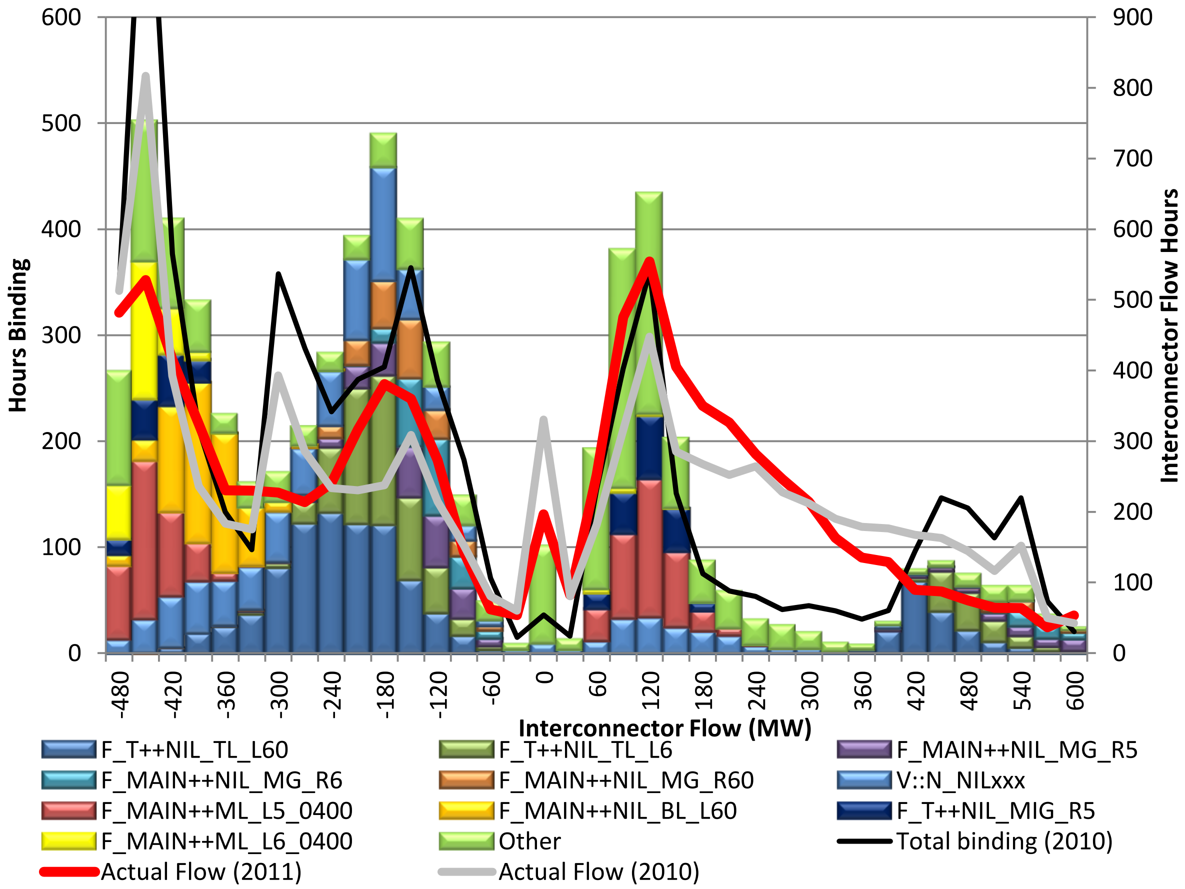

Figure 17: Binding constraint equation distribution for Basslink

Table 11: Binding constraint equations setting the Tas to Vic limit on T-V-MNSP1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
F_T++NIL_TL_L60	964.6 (771.0)	*Tasmania lower 60 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_T++NIL_TL_L6	610.3 (529.3)	*Tasmania lower 6 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_MAIN++NIL_MG_R5	251.1 (165.6)	*Mainland raise 5 minute FCAS requirement for a mainland generation event, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R6	222.2 (301.1)	*Mainland raise 6 second requirement for a mainland generation event, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R60	214.9 (297.2)	*Mainland raise 60 second requirement for a mainland generation event, Basslink able transfer FCAS*
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	185.7 (280.9)	*Out = Nil, avoid overloading the South Morang 500/330 kV (F2) transformer for no contingencies, for radial/parallel modes and Yallourn W1 on the 500 or 220 kV* See Table 3 for comments
F_T++NIL_TL_L5	137.3 (164.6)	*Tasmania lower 5 minute requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
TVBL_ROC	20.3 (19.8)	*Out = Nil, rate of change (Tasmania to Victoria) limit (200 MW / 5 minute) for Basslink*
F_T++LREG_0050	7.0 (9.9)	*Tasmania lower regulation requirement greater than 50 MW, Basslink able transfer FCAS*
T_V_NIL_BL1	6.8 (7.9)	*Out = Nil, Basslink no go zone limits Tasmania to Victoria*

Table 12: Binding constraint equations setting the Vic to Tas limit on T-V-MNSP1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
V::N_NILVxxx & V::N_NILQxxx	814.2 (423.5)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 3 for comments
F_MAIN++ML_L5_0400	681.4 (363.1)	*Mainland lower 5 minute requirement for a mainland load event, Basslink able transfer FCAS*
F_MAIN++NIL_BL_L60	480.8 (423.3)	*Mainland lower 60 second requirement for loss of Basslink, Basslink flow into Tasmania, Basslink able to transfer FCAS*
F_T++NIL_MIG_R5	288.1 (222.5)	*Tasmania raise 5 minute requirement for a Tasmania generation event (loss of the largest inertia), Basslink able to transfer FCAS*
F_MAIN++ML_L6_0400	239.4 (320.8)	*Mainland lower 6 second requirement for a mainland load event, Basslink able transfer FCAS* See Table 4 for comments
F_T++NIL_MG_R6	134.7 (106.4)	*Tasmania raise 6 second requirement for a Tasmania generation event, Basslink able to transfer FCAS*
V_T_NIL_FCSPS	133.3 (972.8)	*Basslink limit from Victoria to Tasmania for load enabled for the Basslink frequency control system protection scheme (FCSPS)* See Table 3 for comments
F_T++NIL_MG_R60	107.3 (30.2)	*Tasmania raise 60 second requirement for a Tasmania generation event, Basslink able to transfer FCAS*
F_MAIN++ML_L60_0400	76.8 (78.6)	*Mainland lower 60 second requirement for a mainland load event, Basslink able transfer FCAS*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
VT_000	73.8 (6.1)	*Victoria to Tasmania on Basslink upper transfer limit of 0 MW* This constraint equation is invoked when Basslink is out of service (along with the constraint equation TV_000). In 2011 Basslink was out of service for a total of 4.4 days compared to 0.6 days in 2010. See Table 19.

9.4 Victoria to NSW (VIC1-NSW1)

The Victoria to NSW interconnector comprises the 330kV lines between Murray and Upper Tumut (65), Murray and Lower Tumut (66), Jindera and Wodonga (060) and the 220 kV line between Buronga and Red Cliffs (0X1). This interconnector was formed on 1 July 2008 as a part of the Snowy region abolition and replaced the previous “SNOWY1” and “V-SN” interconnectors. Some of the existing stability limits are still defined for these interconnectors and AEMO has translated these to work with the “new” interconnector.

VIC1-NSW1 can bind in either direction for high demand in NSW or Victoria. Transfer from Victoria to NSW is mainly limited by the transient stability limit for a fault and trip of a Hazelwood to South Morang line or the thermal limits on the South Morang F2 transformer or the Murray to Upper Tumut line. Transfer from NSW to Victoria is mainly limited by voltage collapse for loss of the largest Victorian generator or the thermal limits on the Murray to Dederang or Wagga to Lower Tumut (051) lines.

The hours at each flow level on VIC1-NSW1 were very similar in 2010 and 2011. The binding hours were similar for flows into Victoria and low flows into NSW. However, flows into NSW at higher levels were constrained for a larger number of hours in 2011 compared to 2010 (see Figure 19).

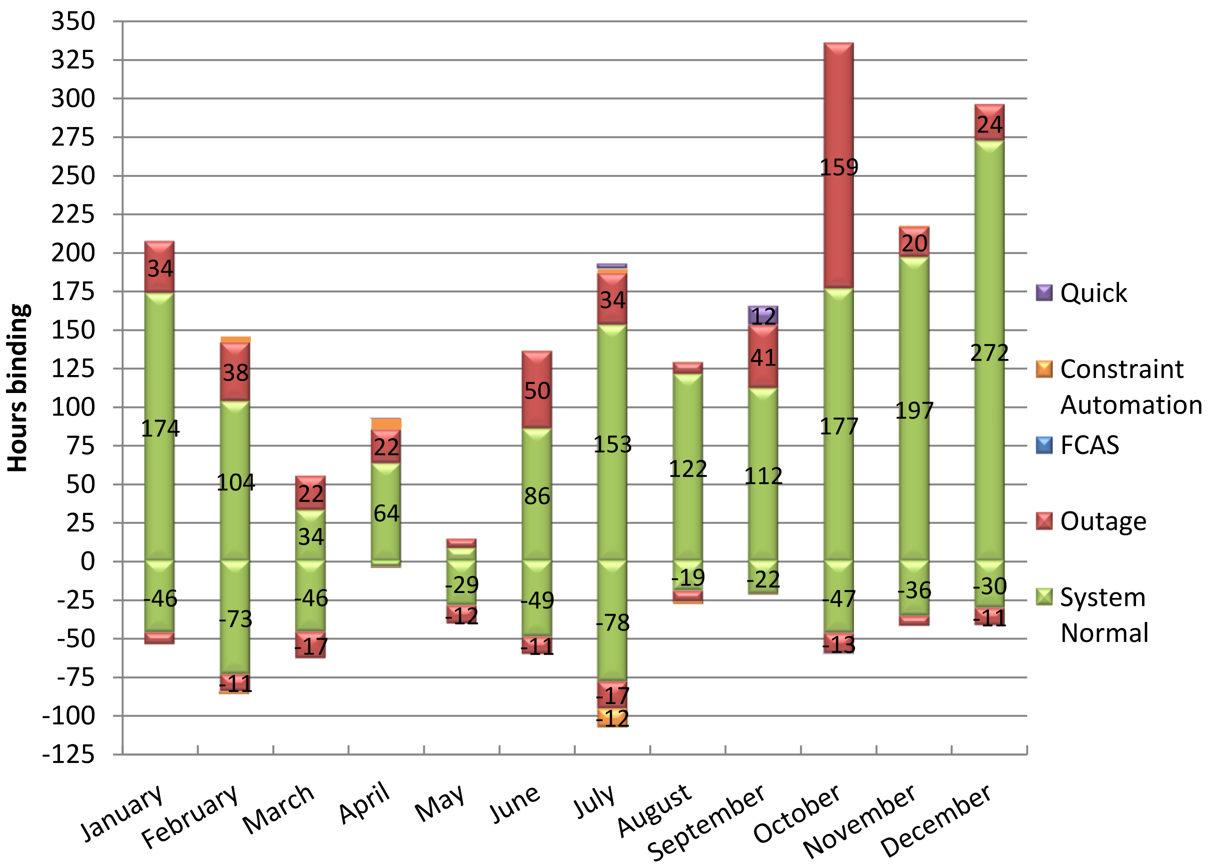

Figure 18: Categorized binding intervals per month for VIC1-NSW1

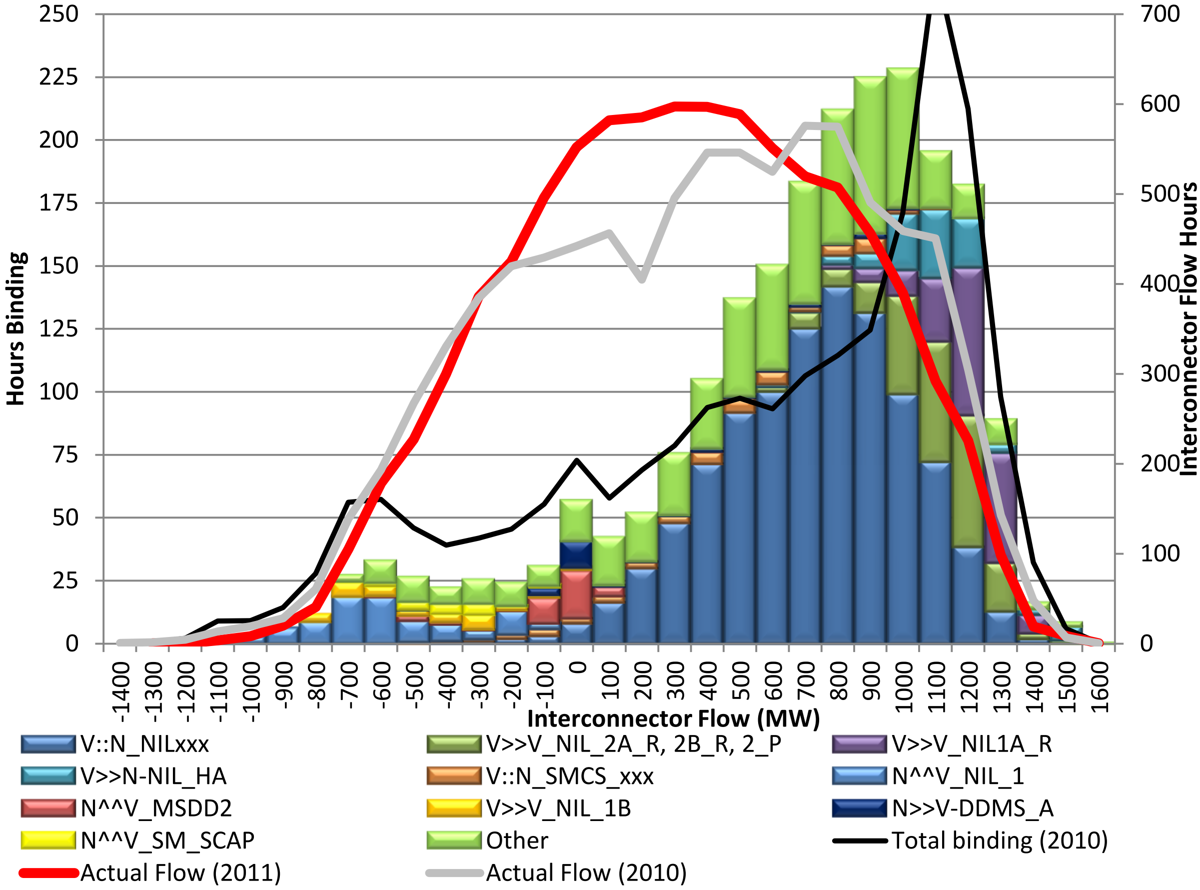

Figure 19: Binding constraint equation distribution for VIC1-NSW1

Table 13: Binding constraint equations setting the Vic to NSW limit on VIC1-NSW1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
V::N_NILVxxx & V::N_NILQxxx	993.8 (496.8)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 3 for comments
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	189.7 (293.3)	*Out = Nil, avoid overloading the South Morang 500/330 kV (F2) transformer for no contingencies, for radial/parallel modes and Yallourn W1 on the 500 or 220 kV* See Table 3 for comments
V>>V_NIL1A_R	151.3 (6.8)	*Out = Nil, avoid overloading a South Morang to Dederang 330 kV line for trip of the parallel line* See Table 3 for comments
V>>N-NIL_HA	92.0 (445.8)	*Out = Nil, avoid overload on Murray to Upper Tumut (65) 330 kV line on trip of Murray to Lower Tumut (66) 330 kV line* See Table 3 for comments
V::N_SMCS_xxx	44.5 (44.3)	*Out = South Morang 330 kV series capacitor, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* There are 12 constraint equations that make up the transient stability export limit from Victoria for this outage and all the binding results have been combined.
V::V_DDSM	40.4 (9.8)	*Out = Dederang to South Morang 330 kV line, avoid transient instability for fault and trip of remaining Dederang to South Morang 330 kV line*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		The Dederang to South Morang lines (#1 or #2) were out for a total of 3.1 days in 2011 compared to 4.3 days in 2010 - see Table 19.
V>>V_NIL_5	35.9 (0)	Out = Nil, avoid overloading either Mount Beauty to Dederang 220 kV line (flow to North) for trip of the other Mount Beauty to Dederang 220 kV line
V::N_BUDP_xxx	32.1 (0)	*Out = Buronga to Darlington Point 220 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 10 for comments
V::N_DDMS_xxx	30.3 (0)	*Out = Dederang to Murray 330 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 10 for comments
V::V_EPTT	21.8 (8.9)	*Out = Eildon to Thomastown 220 kV line, avoid transient instability for fault and trip of a Dederang to South Morang 330 kV line* The Eildon to Thomastown line was out for a total of 11.4 days in 2011 compared to 2 days in 2010 - see Table 19.

Table 14: Binding constraint equations setting the NSW to Vic limit on VIC1-NSW1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
N^^V_NIL_1	86.2 (93.7)	*Out = Nil, avoid voltage collapse for loss of the largest Victorian generating unit* This constraint equation bound and set the interconnector limit for periods from late April through to early September. It is expected to bind for a similar number of hours in 2012.
N^^V_MSDD2	37.2 (0.4)	*Out = Dederang to Murray 330 kV line, avoid voltage collapse for trip of the remaining Dederang to Murray 330 kV line* One Dederang to Murray (#1 or #2) line was out for a total of 13.3 days in 2011 compared to 0.9 days in 2010 - see Table 19. This constraint equation or N^^V_MSDD2 bound instead of N^^V_NIL_1.
V>>V_NIL_1B	27.8 (72.9)	*Out = Nil, avoid overloading Dederang to Murray #2 330 kV line for trip of the Dederang to Murray #1 330 kV line* This constraint equation bound from mid May through to early June 2011.
N>>V-DDMS_A	20.1 (0)	*Out = one of Dederang to Murray 330 kV line, avoid overloading the remaining Murray to Dederang 330 kV line on trip of Lower Tumut to Wagga (051) 330 kV line subsequent tripping of 970, 990 and 99M (out of Yass) 132 kV lines* This constraint equation models a control scheme for the 132 kV lines between Wagga and Yass. These lines are consecutively tripped if they overload on trip of 051 line (unless the Wagga to Yass 132 kV network is radialised under high import into NSW from Victoria).
N^^V_SM_SCAP_R & N^^V_SM_SCAP_P	15.1 (0)	*Out = South Morang 330 kV series capacitor, avoid voltage collapse on trip of the largest Victorian generating unit* There are 2 constraint equations that make up the voltage stability export limit from Victoria to South Australia and all the binding results have been combined.
N^^V_MSDD1	12.2 (0)	*Out = Murray to Dederang #1 or #2 330 kV line, avoid voltage collapse for trip of the largest Victorian generating unit or Basslink* See comment for N^^V_MSDD2 above.

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
N^^V_JNWO	5.1 (0)	*Out = Jindera to Wodonga 330 kV line, avoid voltage collapse for trip of the largest Victorian generating unit* The Jindera to Wodonga line was out for 0.5 days in 2011 and zero days in 2010 - see Table 19. This constraint equation bound instead of N^^V_NIL_1.
N>>V-LTMS_5	4.3 (1.9)	*Out = Lower Tumut to Murray (66) 330 kV line, avoid overloading Upper Tumut to Murray (65) 330 kV line on trip of Lower Tumut to Wagga (051) 330 kV line subsequent tripping of 970, 990 and 99M (out of Yass) 132 kV lines* This constraint equation models a control scheme for the 132 kV lines between Wagga and Yass. These lines are consecutively tripped if they overload on trip of 051 line (unless the Wagga to Yass 132 kV network is radialised under high import into NSW from Victoria).
V>>V_TTSB1_SMTT_2A_R	2.3 (0)	*Out = Thomastown #1 220 kV bus with both South Morang to Thomastown 220 kV lines switched to Thomastown #3 220 kV bus, avoid overloading Richmond to Brunswick 220 kV cable on trip of South Morang (F2) 500/330 kV transformer, radial mode, Yallourn W1 on 500 kV* This bus and line configuration was in place for 5 days (see Table 19) as a part of the refurbishment of the Thomastown substation.
V>>V_KTSM_4_R	2.2 (0)	*Out = Keilor to South Morang 500 kV line, avoid overloading a South Morang to Sydenham 500 kV line on trip of the remaining South Morang to Sydenham 500 kV line, Yallourn Unit 1 in 220 kV mode, radial mode* The Keilor to South Morang line was out for a total of 4.4 days in 2011 compared to 4.7 days in 2010 - see Table 19.

9.5 Heywood interconnector (V-SA)

The Vic – SA (or Heywood) interconnector is an AC interconnector between Heywood in Victoria and South East in South Australia. It was originally commissioned in 1989 as a connection from the western 500 kV network in Victoria to the nearest 275 kV substation in South Australia, Para. It includes a number of connections to the parallel 132 kV network in south eastern SA. Up until recently the vast majority of the time the flow was from Victoria to SA. With an increasing number of wind farms in SA the flow is now often from SA to Victoria. In March 2010 the limit from SA to Victoria on Heywood was increased from 300 to 460 MW and the combined Heywood and Murraylink limit was increased to 580 MW in January 2011. In December 2011 the voltage collapse limit from Victoria to South Australia was revised to use the largest South Australian generation contingency (the previous version was only for loss of a Northern unit). This increased the limit on average by 50 MW.

Victoria to SA flow is most often restricted by the voltage collapse limit in south east SA. Export from SA is mainly restricted by the thermal limits on the South East substation 275/132 kV transformers and the South Morang F2 transformer. V-SA appears in many of the Victorian constraint equations and these can limit both directions of flow on this interconnector.

The hours at each flow level on V-SA were very similar in 2010 and 2011 except for a greater number of hours for high flows into South Australia (greater than 270 MW). The binding hours in 2011 were higher for greater than 270 MW flow into South Australia (even allowing for the higher number of hours in 2011) – see Figure 21.

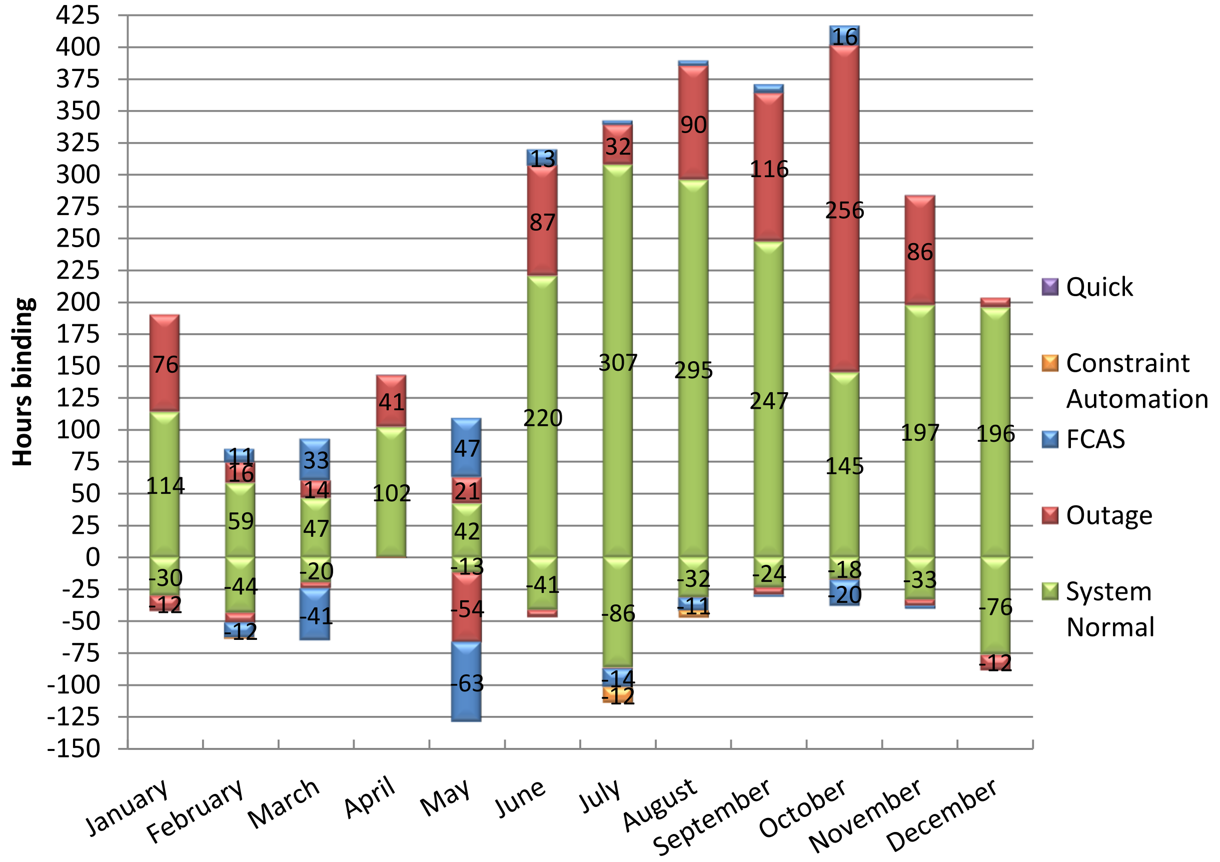

Figure 20: Categorized binding intervals per month for V-SA

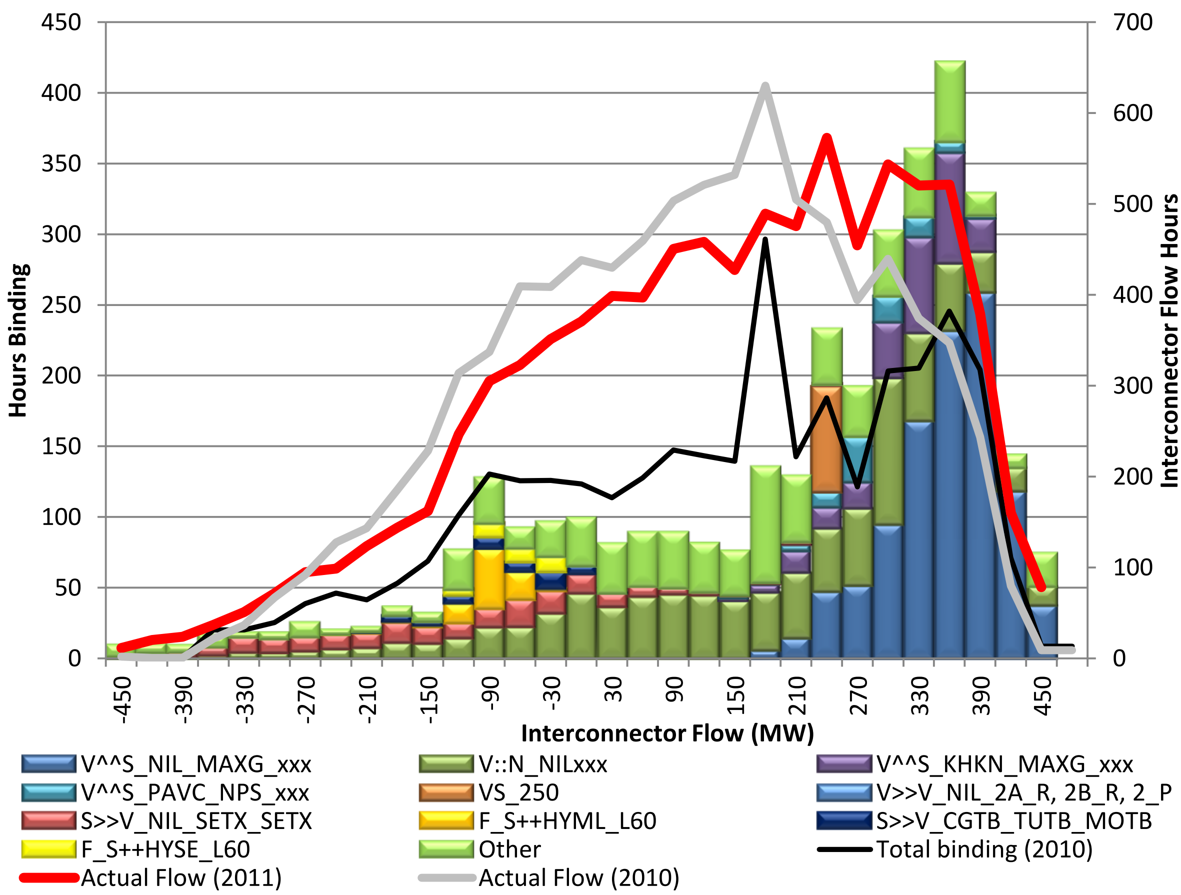

Figure 21: Binding constraint equation distribution for V-SA

Table 15: Binding constraint equations setting the Vic to SA limit on V-SA

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
V^^S_NIL_NPS_xxx & V^^S_TBCP_NPS_xxx & V^^S_NIL_MAXG_xxx	1026.7 (542.0)	*Out = Nil, Victoria to SA long term voltage stability limit for loss of the largest credible generation contingency in SA, South East capacitor bank on / off, Tailem Bend capacitor bank on/off* See Table 3 for comments
V::N_NILVxxx & V::N_NILQxxx	863.8 (429.9)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 3 for comments
V^^S_KHKN_MAXG_xxx	263.0 (0)	*Out = Keith to Kincraig 132 kV line, Victoria to SA long term voltage stability limit for loss of a Northern unit, South East capacitor bank on / off* See Table 3 for comments
V^^S_PAVC_NPS_xxx	92.0 (124.4)	*Out = one Para SVC, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off* There are 2 constraint equations that make up the voltage stability export limit from Victoria to South Australia and all the binding results have been combined.
VS_250	74.3 (25.5)	*Victoria to South Australia on Heywood upper transfer limit of 250 MW* This constraint equation is included in a number of constraint sets which are used for outages of the 500 kV lines in from Sydenham to Heywood and the 275 kV lines from Heywood to South East.
F_ESTN++HYML_L60	53.5 (184.8)	*Out = one Heywood to Moorabool or one Moorabool to Sydenham 500 kV line, Eastern lower 60 second requirement* The Heywood to Moorabool line was out for a total of 11 days in 2011 compared to 27.3 days in 2010 - see Table 19.
V>>S_HYML_2	40.3 (67.1)	*Out = Heywood to Moorabool to Aloca Portland 500 kV line, avoid overloading Heywood 500/275 kV (M1 or M2) transformer for trip of Northern Power Station unit 2* This constraint equation is used in the Heywood to Moorabool line and the Heywood 500/275 kV transformer outage constraint sets. These elements were out for a total of 25.8 days in 2011 compared to 40.6 days in 2010 - see Table 19.
V::N_SMCS_xxx	38.8 (40.2)	*Out = South Morang 330 kV series capacitor, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 13 for comments
V>>S_HYML_1	30.6 (66.7)	*Out = Heywood to Moorabool to Alcoa Portland 500 kV line, avoid overloading Heywood 500/275 kV (M1 or M2) transformer for trip of Northern Power Station unit 1* See comment on V>>S_HYML_2
V::N_BUDP_xxx	29.8 (0)	*Out = Buronga to Darlington Point 220 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 10 for comments

Table 16: Binding constraint equations setting the SA to Vic limit on V-SA

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	195.7 (287.1)	*Out = Nil, avoid overloading the South Morang 500/330 kV (F2) transformer for no contingencies, for radial/parallel modes and Yallourn W1 on the 500 or 220 kV*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		See Table 3 for comments
S>>V_NIL_SETX_SETX	195.3 (203.6)	*Out = Nil, avoid overloading a South East 275/132 kV transformer on trip of the remaining South East 275/132 kV transformer* See Table 3 for comments
F_S++HYML_L60	77.4 (52.0)	*Out = one Heywood to Moorabool 500 kV line or one Moorabool to Sydenham 500 kV line, SA lower 60 second requirement* See Table 6 for comments
S>>V_CGTB_TUTB_MOTB	46.5 (0)	*Out = Cherry Gardens to Tailem Bend 275 kV line, avoid overloading Mobilong to Tailem Bend 132 kV line on trip of Tailem Bend to Tungkillo 275 kV line* The Cherry Gardens to Tailem Bend line was out for a total of 6.1 days in 2011 compared to zero days in 2010 - see Table 19.
F_S++HYSE_L60	36.7 (45.4)	*Out = one Heywood to South East 500 kV line or one Heywood 500/275 kV (M1 or M2) transformer, SA lower 60 second requirement* The Heywood to Moorabool line was out for a total of 11 days in 2011 compared to 27.3 days in 2010 - see Table 19.
F_S++HYML_L6	23.8 (6.8)	*Out = one Heywood to Moorabool 500 kV line or one Moorabool to Sydenham 500 kV line, SA lower 6 second requirement* See comment on F_S++HYSE_L60
F_S++HYML_L5	21.5 (6.8)	*Out = one Heywood to Moorabool 500 kV line or one Moorabool to Sydenham 500 kV line, SA lower 5 minute requirement* See comment on F_S++HYSE_L60
S:V_420	12.6 (0)	*South Australia to Victoria on both Heywood and Murraylink maximum transfer limit to avoid oscillatory instability* This constraint equation was added, in January 2011, to a number of outage constraint sets across the NEM (except for Tasmania). The 420 MW value is the previous system normal limit. Throughout 2011 AEMO conducted studies as to whether the 420 MW limit was appropriate for various outages. In some cases the limit was increased. This work will continue in 2012.
CA_SPS_3D47601E_02	12.2 (0)	*Constraint Automation, avoid overloading Brunswick to Richmond 220 kV cable on trip of South Morang 500/330 kV (F2) transformer* Created on 31 July 2011 to manage the lower rating of the Brunswick to Richmond 220 kV cable. The lower rating of 450 MVA was in place for 24 hours due to the cable flow exceeding the 400 MVA earlier in the day. A new constraint automation constraint equation was required following the return to service of the Hazelwood (A1) 500/220 kV transformer (see also constraint equation CA_SPS_3D470CCA in Table 18).
S>NIL_CGTB_TUTB	9.5 (0)	*Out = Nil, avoid overloading Tungkillo to Tailem Bend 275 kV line on trip of Cherry Gardens to Tailem Bend 275 kV line* This constraint equation was new in February 2011. This constraint equation only binds with high export from South Australia to Victoria. In 2011 this occurred in February and early March.

9.6 Murraylink (V-S-MNSP1)

Murraylink is a 220 MW DC link between Red Cliffs in Victoria and Monash in South Australia, which was commissioned in 2002. Transfers from Victoria to South Australia are mainly limited by constraint equations that affect the export from Victoria as a whole, such as the South Morang F2 transformer overload, or the transient stability limit for exports from Victoria. Many of the thermal issues closer to Murraylink are dealt with by the Murraylink runback scheme. Transfers from SA to Victoria are limited by the 132 kV lines from Robertstown to Monash and Robertstown to Waterloo as well as the Robertstown 275/132 kV transformers.

The hours at each flow level on Murraylink were almost the same in 2010 and 2011. The binding hours were very similar except for high flows (greater than 100 MW) from SA to Vic where the binding hours were higher in 2011 (see Figure 23).

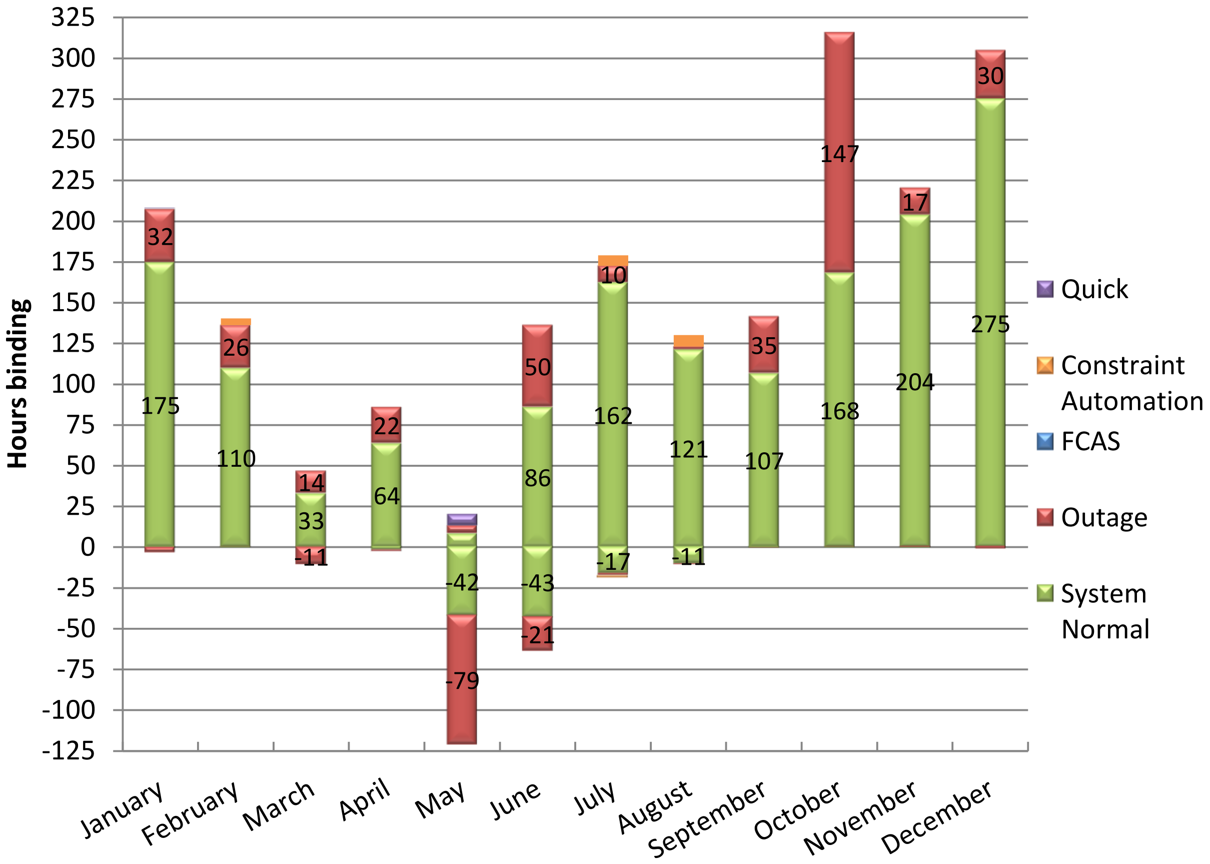

Figure 22: Categorized binding intervals per month for V-S-MNSP1

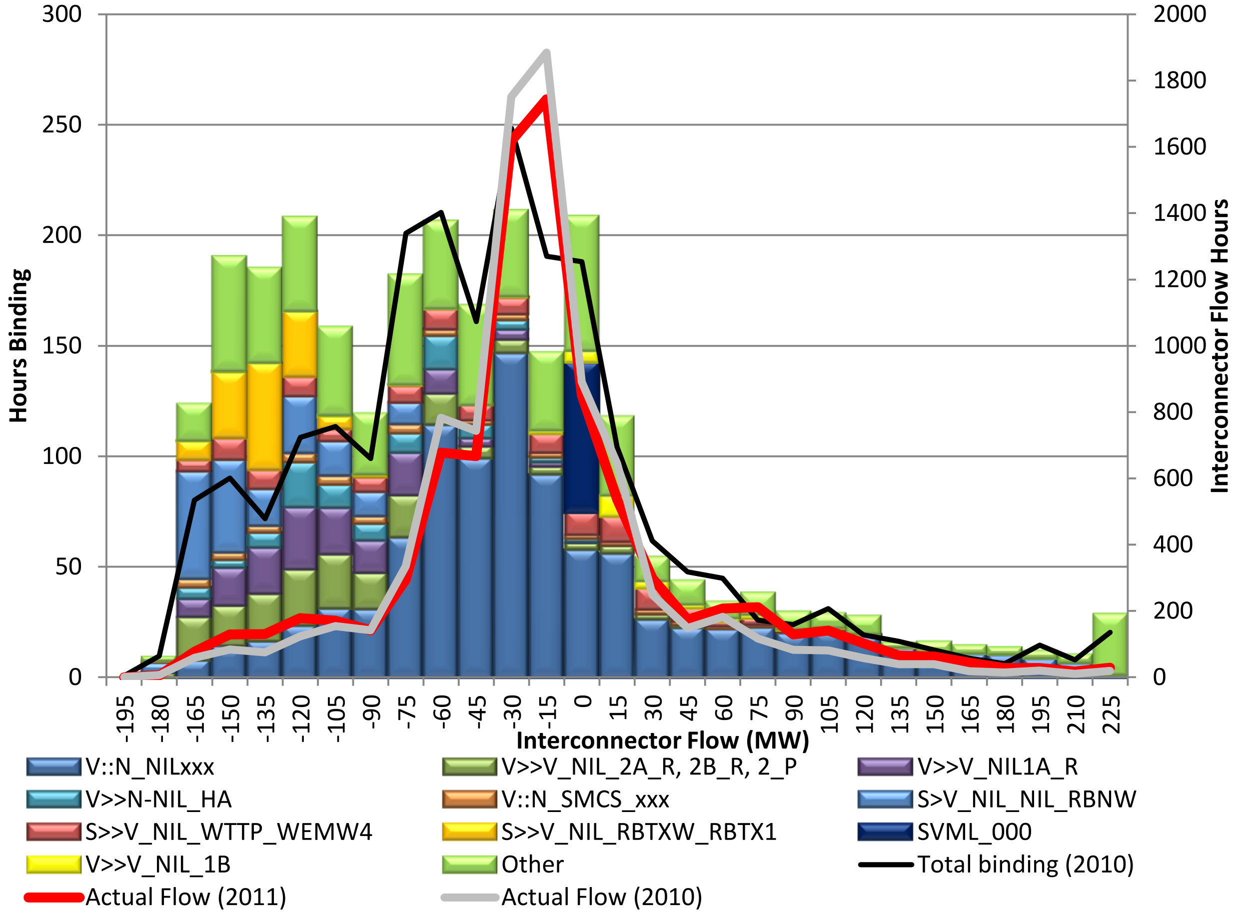

Figure 23: Binding constraint equation distribution for Murraylink

Table 17: Binding constraint equations setting the Vic to SA limit on V-S-MNSP1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
V::N_NILVxxx & V::N_NILQxxx	968.3 (495.5)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 3 for comments
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	184.7 (294.5)	*Out = Nil, avoid overloading the South Morang 500/330 kV (F2) transformer for no contingencies, for radial/parallel modes and Yallourn W1 on the 500 or 220 kV* See Table 3 for comments
V>>V_NIL1A_R	151.4 (6.8)	*Out = Nil, avoid overloading a South Morang to Dederang 330 kV line for trip of the parallel line* See Table 3 for comments
V>>N-NIL_HA	92.8 (438.2)	*Out = Nil, avoid overload on Murray to Upper Tumut (65) 330 kV line on trip of Murray to Lower Tumut (66) 330 kV line* See Table 3 for comments
V::N_SMCS_xxx	44.5 (44.3)	*Out = South Morang 330 kV series capacitor, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 13 for comments
VSML_000	41.4 (46.2)	*Victoria to South Australia on Murraylink upper transfer limit of 0 MW* This constraint equation is normally invoked for Murraylink out of service. Murraylink was out for a total of 5.2 days in 2011 compared to 3.2 days in

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		2010 - see Table 19.
V>>V_NIL_5	36.6 (0)	*Out = Nil, avoid overloading either Mount Beauty to Dederang 220 kV line (flow to North) for trip of the other Mount Beauty to Dederang 220 kV line* See Table 13 for comments
V::V_DDSM	34.3 (9.8)	*Out = Dederang to South Morang 330 kV line, avoid transient instability for fault and trip of remaining Dederang to South Morang 330 kV line* See Table 13 for comments
V::N_BUDP_xxx	32.1 (0)	*Out = Buronga to Darlington Point 220 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 10 for comments
V::N_DDMS_xxx	30.1 (0)	*Out = Dederang to Murray 330 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* See Table 10 for comments

Table 18: Binding constraint equations setting the SA to Vic limit on V-S-MNSP1

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
S>V_NIL_NIL_RBNW	174.0 (136.9)	*Out = Nil, avoid overloading the North West Bend to Robertstown 132 kV line on no line trips* See Table 3 for comments
S>>V_NIL_WTTP_WEMW4	127.8 (21.9)	*Out = Nil, avoid overloading the Waterloo East to Morgan Whyalla pump 4 132 kV line on trip of the Waterloo to Templers 132 kV line* See Table 3 for comments
S>>V_NIL_RBTXW_RBTX1	123.7 (0)	*Out = Nil, avoid overloading Robertstown #1 275/132 kV transformer on trip of the Robertstown #2 275/132 kV transformer* See Table 3 for comments
SVML_000	67.4 (23.8)	*South Australia to Victoria on Murraylink upper transfer limit of 0 MW* This constraint equation is normally invoked for Murraylink out of service. Murraylink was out for a total of 5.2 days in 2011 compared to 3.2 days in 2010 - see Table 19.
V>>V_NIL_1B	29.3 (76.6)	*Out = Nil, avoid overloading Dederang to Murray #2 330 kV line for trip of the Dederang to Murray #1 330 kV line* See Table 14 for comments
S>>V_NIL_RBTX2_RBTX1	14.8 (0)	*Out = Nil, avoid overloading Robertstown #1 275/132 kV transformer on trip of Robertstown #2 275/132 kV transformer* See Table 6 for comments
S:V_420	11.2 (0)	*South Australia to Victoria on both Heywood and Murraylink maximum transfer limit to avoid oscillatory instability* See Table 16 for comments
CA_SPS_3D47601E_02	7.8 (0)	*Constraint Automation, avoid overloading Brunswick to Richmond 220 kV cable on trip of South Morang 500/330 kV (F2) transformer* See Table 16 for comments
S>>V_PARS_RBTX_RBTX	6.8 (0)	*Out = Para to Roseworthy or Dorrien to Roseworthy 132 kV line, avoid overloading a Robertstown 275/132 kV transformer on loss of the other*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2010)	*DESCRIPTION* / NOTES
		Robertstown 275/132 kV transformer The Dorrien to Roseworthy line was out for a total of 18.7 days in 2011 compared to 10.2 days in 2010 - see Table 19 for comments
CA_SPS_3D47601E_02	7.8 (0)	*Constraint Automation, avoid overloading Brunswick to Richmond 220 kV cable on trip of South Morang 500/330 kV (F2) transformer* See Table 16 for comments
S>>V_PARS_RBTX_RBTX	6.8 (0)	*Out = Para to Roseworthy or Dorrien to Roseworthy 132 kV line, avoid overloading a Robertstown 275/132 kV transformer on loss of the other Robertstown 275/132 kV transformer* The Dorrien to Roseworthy line was out for a total of 18.7 days in 2011 compared to 10.2 days in 2010 - see Table 19. With the commissioning of the Templers West substation and associated line re-arrangements this constraint equation has been removed.
CA_SPS_3D470CCA_02	5.8 (0)	*Constraint Automation, avoid overloading Brunswick to Richmond 220 kV cable on trip of South Morang 500/330 kV (F2) transformer* Created on 31 July 2011 to manage the lower rating of the Brunswick to Richmond 220 kV cable. The lower rating of 450 MVA was in place for 24 hours due to the cable flow exceeding the 400 MVA earlier in the day..At the same time there was an outage of the Hazelwood (A1) 500/220 kV transformer which increased the flows on the Brunswick to Richmond cable. Also see CA_SPS_3D47601E_02 in Table 16 for comments

10 Transmission outages

10.1 Major outages

The following table shows the duration of the network outages in 2011 that required any of the binding constraint equations included in the tables in sections 7, 8 and 9 to be invoked. This list excludes the "#" constraint equations as these are generally not associated with a particular outage.

The outage times were calculated from the times that the constraint sets were invoked.

Table 19: Top 40 outages associated with binding constraint equations

CONSTRAINT SET ID	DAYS	*OUTAGE* / NOTES
N-MBTE_1	194.3 (243.0)	*One Directlink cable*
N-X_MBTE_2	90.0 (121.1)	*Two Directlink cables*
S-KHKN	28.5 (0)	*Keith to Kincraig 132 kV line* These outages were due to installation of optic fibre earth wire
N-ARTW_86	22.3 (0)	*Armidale to Tamworth (86) 330 kV line* The constraint set for Armidale to Tamworth line prior to March 2011 applied for both 85 and 86 lines. To improve dispatch and pre-dispatch performance separate constraint sets were implemented in March 2011. The original set N-ARTW_85 was invoked for 4 days in 2010. The outages for this line were mainly for work to increase the rating of the 86 line.
Q-X_RLSP_BKRL_TRSP & Q-X_RLSP_TRSP	22.1 (0)	*Rocklea to South Pine (809) and Tarong to South Pine (832) 275 kV lines* These constraint sets were constructed for the multiple outage case

CONSTRAINT SET ID	DAYS	*OUTAGE* / NOTES
		following the Queensland floods in January 2011 and the times for both have been combined.
N-KKLS_967	21.9 (25.4)	*Koolkhan to Lismore (967) 132 kV line* The 967 line was out of service at times during 2010 and 2011 for pole replacement work
S-PA_VC_1	20.0 (24.7)	*One Para SVC*
S-DRRS	18.7 (10.2)	*Dorrien to Roseworthy 132 kV line* Outages due to commissioning of Templers West 275 kV substation
N-X_MBTE_3	14.5 (14.2)	*All three Directlink cables*
V-HYTX	13.8 (13.3)	*One Heywood 500/275 kV (M1 or M2) transformer*
V-DDMS	13.3 (0.9)	*One Dederang to Murray (67 or 68) 330 kV line*
V-EPTT_R	11.4 (2.0)	*Eildon to Thomastown 220 kV line* Outage mainly due to the rebuild of Thomastown 220 kV terminal station
V-HYML	11.0 (27.3)	*Heywood to Moorabool 500 kV line*
V-SMSC	9.1 (8.7)	*One or both South Morang 330 kV series capacitors*
S-DVCN	9.1 (5.4)	*Davenport to Canowie 275 kV line* Most of the outage time was due to the installation of a new line reactor
N-CNUT_01	8.8 (1.3)	*Canberra to Upper Tumut (01) 330 kV line*
N-BUDP	6.8 (0.6)	*Buronga to Darlington Point (X5) 220 kV line*
S-SE_TX_1	6.2 (5.0)	*One South East 275/132 kV transformer*
S-CGTB	6.1 (0)	*Cherry Gardens to Tailem Bend 275 kV line*
I-MSUT	5.3 (1.6)	*Murray to Upper Tumut (65) 330 kV line*
I-ML_ZERO	5.2 (3.2)	*Limit Murraylink to zero in either direction*
V-TTS-1B_SMTT_R	5.0 (0)	*Thomastown #1 220 kV bus, both South Morang to Thomastown 220 kV lines switched to Thomastown #3 220 kV bus, Victorian radial mode* Outage due to the rebuild of Thomastown 220 kV terminal station
V-KTSM_R	4.4 (4.7)	*Keilor to South Morang 500 kV line*
I-BL_ZERO	4.4 (0.6)	*Limit Basslink to zero in either direction*
I-LTMS	4.3 (1.1)	*Lower Tumut to Murray (66) 330 kV line*
N-LTUT_64_15M	4.3 (1.3)	*Lower Tumut to Upper Tumut (64) 330 kV line*
I-HYSE	4.0	*One Heywood to South East 275 kV line*

CONSTRAINT SET ID	DAYS	*OUTAGE* / NOTES
	(7.4)	
N-UTYS_2	3.5 (1.2)	*Upper Tumut to Yass (2) 330 kV line*
V-KTSY_R	3.4 (4.8)	*Keilor to Sydenham 500 kV line*
Q-GB_VC	3.1 (2.2)	*Greenbank SVC*
V-DDSM	3.1 (4.3)	*One Dederang to South Morang 330 kV line*
Q-BK_VC	3.0 (19.7)	*Blackwall SVC*
Q-SP_VC	2.8 (8.7)	*South Pine SVC*
V-HYMO	2.6 (0)	*Heywood to Mortlake #2 500 kV line*
N-CHKK_96H	2.5 (3.2)	*Coffs Harbour to Koolkhan (96H) 132 kV line*
Q-X_GGWO_GGGLD_SP_VC	2.2 (0)	*Woolooga to Gin Gin (815 or 816) and Gin Gin to Gladstone (813 or 814) 275 kV lines and South Pine SVC*
N-ARTW_85	2.0 (4.0)	*Armidale to Tamworth (85) 330 kV line* See note on N-ARTW_86
NSA-Q_BARCALDN	1.9 (0)	*Clermont to Lilyvale (7153) 132 kV line, Network Support Agreement for Barcaldine GT to meet local islanded demand at Clermont and Barcaldine* This NSA constraint set is included as it is only invoked under outage conditions
V-HY_MO_ML	1.5 (0)	*Heywood to Mortlake or Mortlake to Moorabool 500 kV line*
S-SE_TX+VC	0.9 (0)	*One South East 275/132 kV transformer and one South East SVC*

10.2 Trends for submit times

The following graph shows the trends on the length of time from when a network outage is submitted to AEMO’s network outage schedule (NOS) and the outage start time. The times are categorized into 4 categories:

- Unplanned: the outage was submitted on or after the start time for the outage.
- Short-notice: the outage was submitted within 4 days of the start time
- ≤ 30 days: the outage was submitted within 30 days of the start time
- > 30 days: the outage was submitted greater than 30 days of the start time

Where an outage was submitted previously and then rescheduled for a new time this is recorded as a new outage in the NOS. Outages for multiple items of related plant which are submitted in a single entry are only counted as a single outage.

The following trends have been noted:

- 80% of the outages from APT (who operate Murraylink and Directlink DC cables) are forced or short notice
- For other NSPs less than 10% of outages are forced and majority of the outages are either short notice or within 30 days

- Compared to other TNSPS ElectraNet, TransGrid and Transend have a higher percentage of outages submitted greater than 30 days
- Very few outages are submitted by Essential Energy, Powerlink, SPAusNet or APT for greater than 30 days out

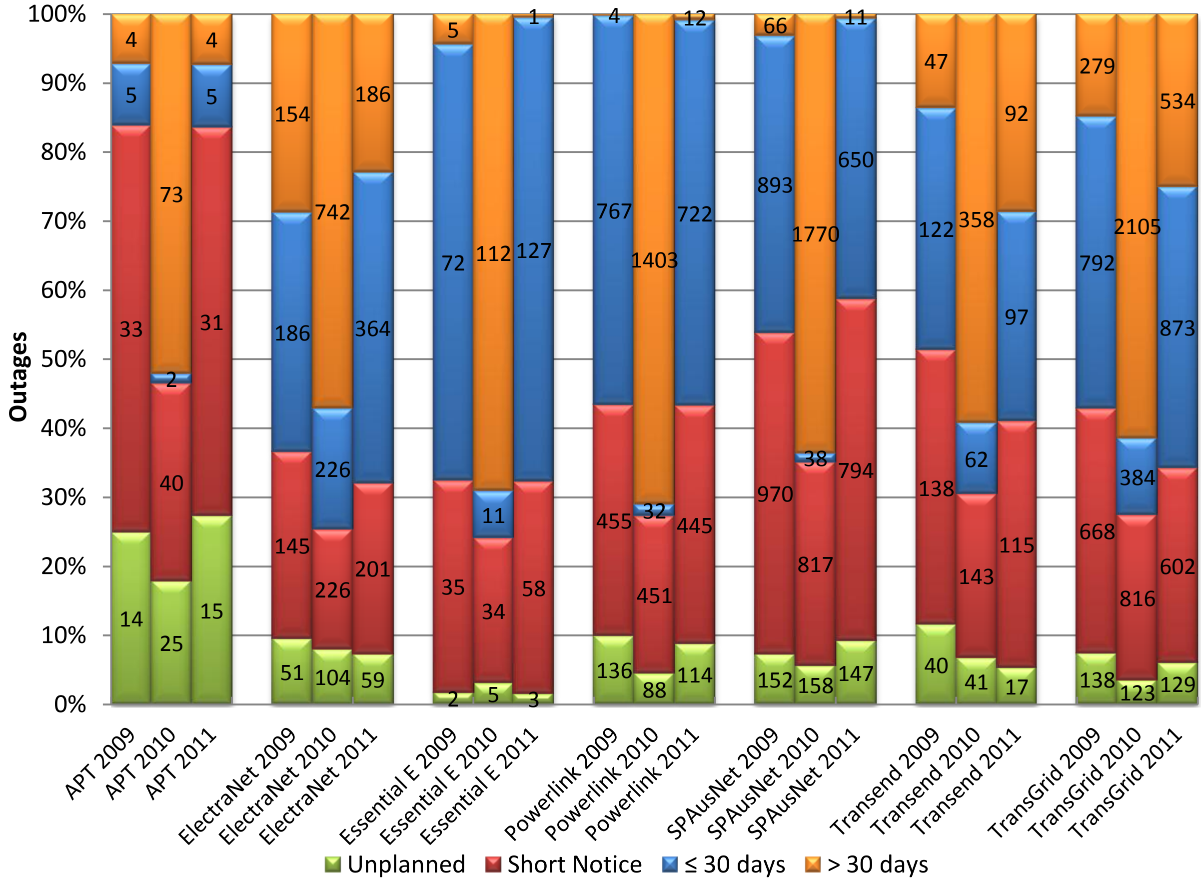

Figure 24 - Outage submit times

11 Other developments

11.1 Constraint automation

The constraint automation is an application in AEMO's EMS which generates thermal overload constraint equations based on the current or planned state of the power system. AEMO's intention is that the constraint automation will eventually create and invoke all of the required thermal constraint equations in real time automatically. This goal is being achieved via a staged implementation with long periods of testing and confirmation of results in between. Currently the first 2 stages have been implemented.

In August 2011 AEMO released a discussion paper on the future of the constraint automation[8].

11.1.1 Stage 1

Stage 1 was made available for use in December 2007. This stage allows building thermal overload constraint equations from a study case with the constraint equations being sent to the market systems manually and the constraint sets invoked manually. This stage is only intended for use in scenarios where there are no existing constraint equations available or the existing ones are

[8] http://www.aemo.com.au/electricityops/0200-0017.html

not working correctly. Stage 1 includes all the constraint equations in a single constraint set and these have unique IDs as they are intended for single use only.

11.1.2 Stage 2

The second stage of the constraint automation delivered incremental improvements to help reduce issues and support further automation of the process. The majority of items for stage 2 were delivered in mid 2010 and these included:

- Operating margins set to AEMO standard for region / voltage level or per transmission element
- Sub-regional loads in Pre-dispatch
- RHS scaling factor thresholds (for compatibility with the new CFG)
- Removing normally off scheduled loads from PASA RHSs
- Improved handling of Yallourn W1 500 / 220 kV switching in PASA. Stage 1 assumed Yallourn W1 was always switched in 500 kV mode. Now the PASA uses the 500 / 220 kV switching mode from the study case used to create the constraint equation.

One item remains to be delivered for stage 2, automating the line flow / transformer flow SPD ID addition to EMS. Currently this is a multi-step manual process and there is a risk that SPD IDs could be missed. This feature will be delivered as a part of stage 3.

11.1.3 Issues

A number of issues were identified with the constraint automation in the first 2 years of its operation. These are detailed in The Constraint Report 2009[9].

No major issues were identified for the constraint automation in 2010 and 2011. In 2011 there were a few cases where a SPD ID was not available (such as during the Queensland floods in January).

The monthly constraint reports[10] detail the usage of the constraint automation as well as any follow up actions.

11.1.4 Usage

Figure 25 below shows the usage of the constraint automation from 2008 to 2011. This usage has been generated based on the constraint sets and does not indicate the number of constraint equations created. The usage is categorised into 4 main areas:

- Invoked
- Control room not invoked. The constraint automation was used to create constraint equations but these were subsequently not invoked. In most of these cases AEMO's control room prepared constraint equations using the constraint automation but the issue was resolved before they were required. In several cases a second constraint set was created as adjustments were required such as increasing an operating margin or including another constraint equation.
- Constraint builders. The constraint automation is used by the constraint builders for two main tasks:
    - Checking the factors on currently invoked constraint equations to confirm they do not require an update. Checking the factors does not require a constraint equation to be sent to the market systems as the factors can be viewed on AEMO's EMS. Due to this the actual constraint builder usage is most likely much higher than reported in Figure 25.

[9] http://www.aemo.com.au/electricityops/0200-0006.html
[10] http://www.aemo.com.au/electricityops/0100-0016.html

- Creation of a constraint equation for a current issue or for short notice multiple outages. This amount does not include any cases where the constraint automation was used in Pre-Production to generate a constraint equation. Use on the Production constraint automation has shifted in 2010 to only for new constraint equations. In cases where only a few factors require changing these are done manually (similar to dot point above).

- Testing the constraint automation. Testing the constraint automation is occasionally performed to test bug fixes or new features. Production testing is only performed as a final check of bugs/features and to confirm that the whole process is working. In general most testing is done on test or pre-production systems or by viewing the results on AEMO's EMS (similar to constraint builder factor checking detailed in the dot point above).

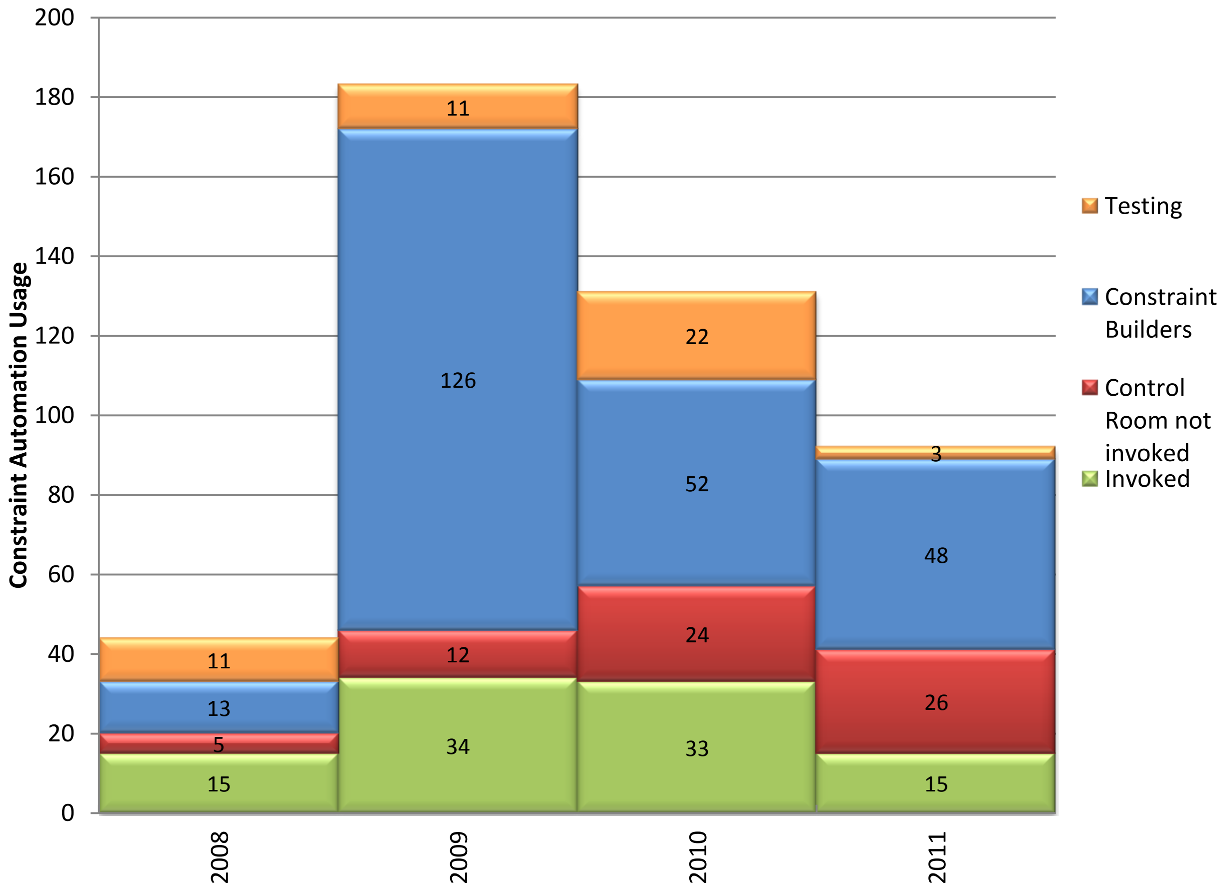

Figure 25: Constraint automation usage

11.2 Congestion information resource

The NER requires AEMO to establish a congestion information resource (CIR) which will consolidate and enhance existing sources of information relevant to the understanding and management of transmission network congestion risk. The interim congestion information resource (CIR) was launched in late 2009. AEMO conducts consultations on the CIR annually.

AEMO conducted a consultation for the first CIR in 2010 and a second consultation in 2011. In 2011 the following items were addressed:

- Dispatch, Pre-dispatch and PASA interconnector and constraint equation results added to the MMS web portal
- Extra fields added to the published NOS. This includes items such as recall times, which was requested in the 2010 CIR consultation and the resubmit reason

- Monthly constraint reports published
- Publication of the Constraint Implementation Guidelines
- Links to NTNDP diagrams
- Links to the augmentation information on TNSP websites

For a full list of the items submitted in the previous CIR consultations please refer to Appendix 1 of the draft Guide to the CIR released as a part of the 2012 consultation: http://www.aemo.com.au/electricityops/0178-0025.html

The CIR is located on the AEMO website: http://www.aemo.com.au/electricityops/congestion.html

This report is included in the CIR.