THE NEM CONSTRAINT REPORT 2010

PREPARED BY: Ben Blake

DOCUMENT REF: ESOPP_30

VERSION: 2

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 special 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.
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

- SO_OP3709 – Generic constraints due to network limitations
- Constraint naming guidelines: http://www.aemo.com.au/electricityops/200-0141.html
- Constraint violation penalty factors: http://www.aemo.com.au/electricityops/140-0011.html
- Constraint formulation guidelines (CFG): http://www.aemo.com.au/electricityops/170-0040.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
- Congestion information resource: http://www.aemo.com.au/electricityops/congestion.html
- The constraint report 2009: http://www.aemo.com.au/electricityops/0200-0006.html

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 2010. It includes the drivers on constraint equation changes in 2010, analysis of binding and violating constraint equations, market impact of constraint equations, interconnector limit setters, 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 2010 report includes a number of additions compared to the 2009 report. These include:

- Market impact of constraint equations
- Binding and violating constraint equation results are directly compared with the 2009 results
- Outage hours compared with 2009 results
- Graphs indicating at which levels of interconnector flow constraint equations bind

- Trends on binding constraint equations

5 Current statistics

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

As of 31st December 2010 there were:

- 3559 constraint sets. This is a slight increase over 2009's total of 3431.
- 8902 constraint equations compared to 8275 in 2009 which is a similar increase on 2008's total of 7697.
- 382 constraint functions which is an increase over 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.

Outage ramping (which would swamp the results) and the constraint automation built constraint equations (full results are in Figure 20) are also excluded from the following graphs which show the breakup of constraint equation by regions, FCAS and a few other types (Figure 1) and by limit type (Figure 2).

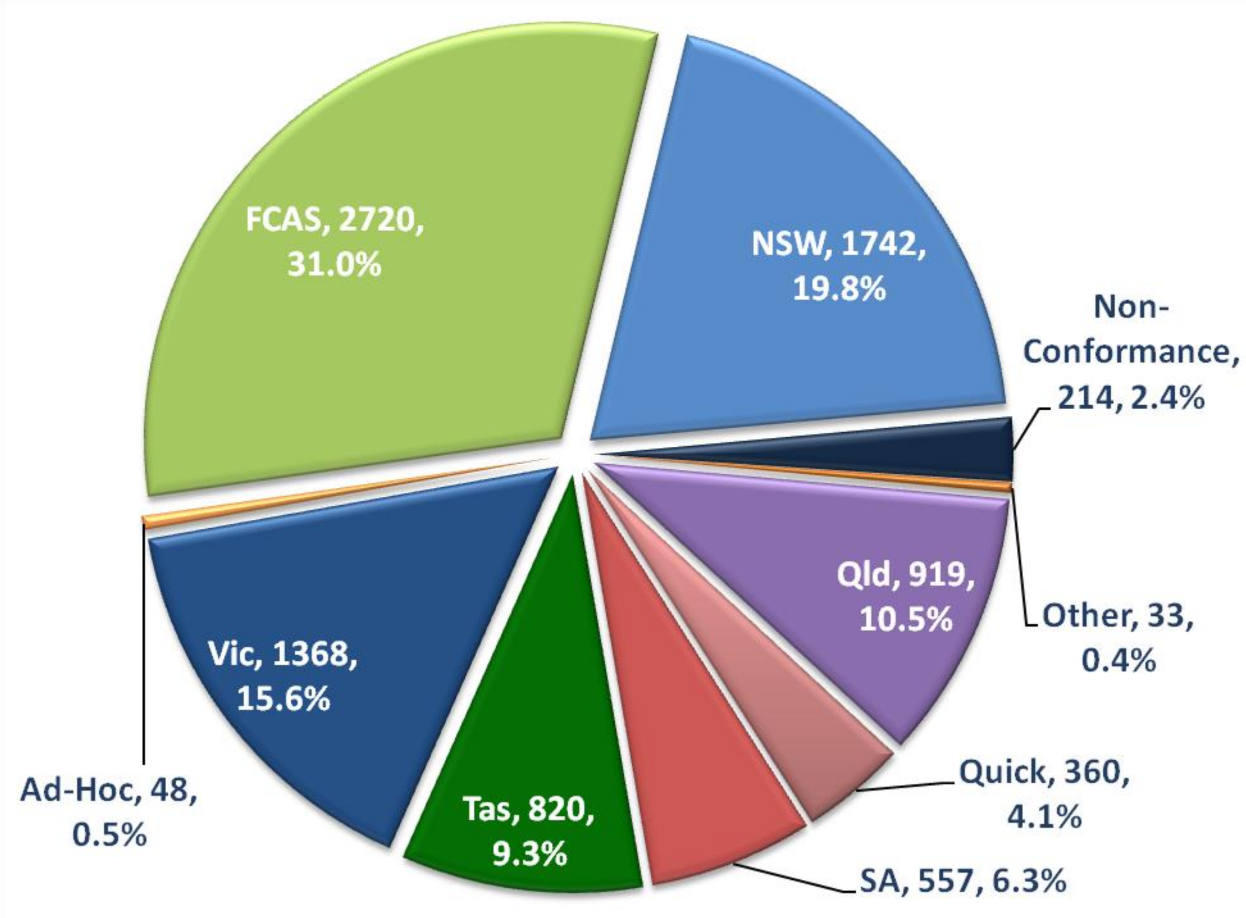

Figure 1: Constraint equations by region/FCAS

As can be seen in the graphs the majority of the constraint equations are for frequency control ancillary services (FCAS) and NSW and this is borne out in the number of constraint equation changes (see 6.3). Additionally the main types of constraint equations are for FCAS (31 %) and thermal overloads (28.8 %) which can be viewed in Figure 2 below.

Compared to 2009 there were a number of changes to the percentage breakup of the constraint equations in 2010. These differences include:

- The number of NSW constraint equations has increased from 1496 to 1742
- Victoria increased from 1171 to 1368
- Minor increases in SA, Tasmania and Queensland
- The number of thermal constraint equations has increased significantly from 1970 to 2402. This increase accounts for the majority of the regional increases.
- FCAS has decreased from 2224 to 1829. This can be attributed to correcting the limit type to "Unit Zero – FCAS" which has incurred a similar increase

Note that in last year's report 160 SA constraint equations were incorrectly allocated to Victoria. Instead of 1331 in Victoria it was actually 1171 and for SA the total of 335 should have been 495.

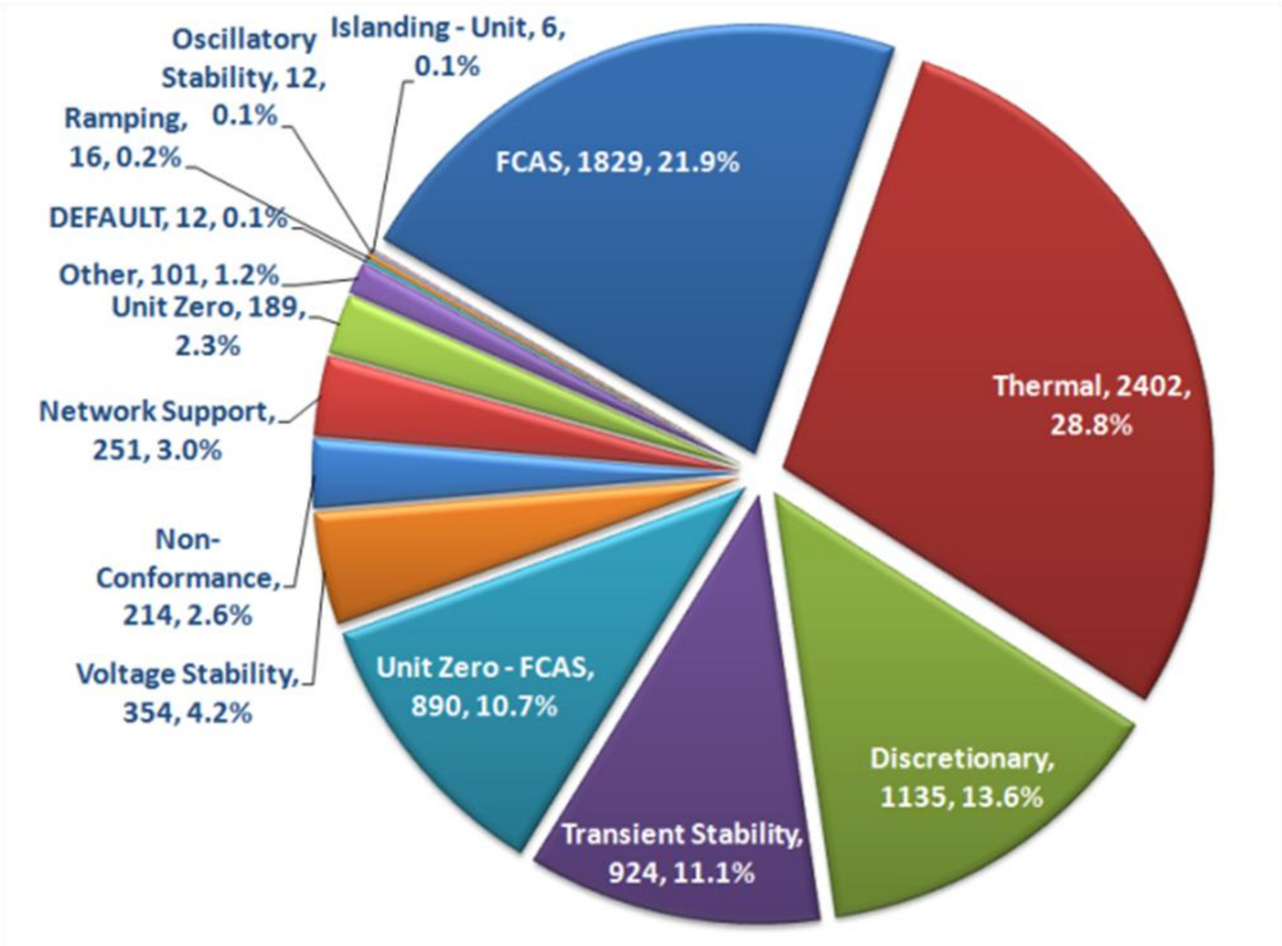

Figure 2: Constraint equations by limit type

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. Currently AEMO's constraint builders can only include generator(s) in constraint equations once the generator(s) are 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 usually generates multiple constraint equation changes.

In general the tables in this section list the substation work and generator registration separately. Only changes that directly cause changes to the constraint equations are listed.

2009 included a significant number of new generators commissioning across all regions as well as major projects in NSW and Queensland. 2010 was markedly different with only 4 new generators commissioned, compared to 13 in 2009, and all of those were in South Australia. The number of transmission changes in 2010 was lower than 2009 (17 versus 21) and this is reflected in the month-by-month changes (see Figure 4).

In 2010 the number of changes was significantly less at 6250 changes compared to 2009's record number of 8592. This is a return to the historical average number of constraint equation changes. 2006, 2008 and 2010 all had similar numbers of changes (approximately 6200) – see Figure 3.

Considering there are fewer planned transmission changes and only a slightly higher number of new generators intending to commission in 2011 it is likely that the number of constraint equation changes next year will be reduced compared to the 2010 number.

6.1 Generators

The following list includes all scheduled and semi-scheduled generators that were added or removed in 2010. Additionally where non-scheduled wind-farms were of a significant size and caused constraint changes these are listed also.

There were only 4 new generators registered along with several existing wind farms converting to semi-scheduled. All work was concentrated in South Australia.

Table 1: Generator changes in 2010

GENERATOR	REGISTRATION DATE	REGION	NOTES
Lake Bonney 3	2 July 2010	South Australia	
Bell Bay GT 1 & 2	6 July 2010	Tasmania	Units deregistered
North Brown Hill wind farm	19 July 2010	South Australia	
Snowtown	26 July 2010	South Australia	Changed to semi-scheduled from scheduled
Waterloo wind farm	20 August 2010	South Australia	
Port Lincoln 3	20 August 2010	South Australia	
Lake Bonney 2	9 September 2010	South Australia	Changed to semi-scheduled from scheduled

6.2 Transmission

In 2010 there was a steady pace in the number of transmission changes. Similar to 2009 both Queensland and New South Wales generated the majority of projects in the year (which is reflected in the number of Constraint changes in those regions). As the major projects in Queensland and NSW are now complete it is expected that there will be fewer transmission changes in 2011.

Table 2: Transmission changes in 2010

PROJECT	DATE	REGION	NOTES
Wollar substation	13 January 2010	NSW	Cut into existing Bayswater to Mt Piper (5A4) 500 kV line
9W2 / 9W7 132 kV lines	6 March 2010	NSW	Reconfiguration of lines to Nambucca and new substation at Boambee South. Part of a larger project to commission a 2nd 132 kV circuit between Coffs Harbour and Kempsey

PROJECT	DATE	REGION	NOTES
NSW 500 kV - 39 cut into Bannaby	16 March 2010	NSW	Sydney West to Yass (39) 330 kV line cut into the new Bannaby substation to form Bannaby to Yass (61) and Bannaby to Sydney West (39) 330 kV lines. See 6.2.2.
9W5 132 kV line	26 March 2010	NSW	Reconfiguration of lines to a new substation at Macksville. Part of a larger project to commission a 2nd 132 kV circuit between Coffs Harbour and Kempsey
Waddamana ring bus	17 March 2010	Tasmania	Tungatinah to Waddamana #2 and Bridgewater to Waddamana lines no longer on a single contingency
Wellington to Wollar (79) 330 kV line	21 May 2010	NSW	New 330 kV line between Wollar and Wellington
Risdon Caps No. 3 & 4	13 June 2010	TAS	Risdon capacitor banks now fully commissioned
Macksville to Nambucca (9W6) 132 kV line	5 June 2010	NSW	Completes 2nd 132 kV circuit between Coffs Harbour and Kempsey
NSW 500 kV – Bayswater unit 3 moved to 500 kV bus	7 June 2010	NSW	See 6.2.2.
Belalie 275 kV substation	1 July 2010	SA	New substation between Davenport and Mokota for North Brown Hill wind farm
NSW 500 kV - 36 cut into Bannaby	11 August 2010	NSW	Marulan to Mt Piper (36) 330 kV line cut into Bannaby. Line is now Bannaby to Marulan (36) 330 kV. See 6.2.2.
NSW 500 kV - remaining 36 converted to 5A7	15 August 2010	NSW	Remaining section of Marulan to Mt Piper (36) 330 kV line cut into Bannaby and recommissioned as Bannaby to Mt Piper (5A7) 500 kV. See 5.2.2.
NSW 500 kV - 35 cut into Bannaby	25 August 2010	NSW	Marulan to Mt Piper (35) 330 kV line cut into Bannaby. Line is now Bannaby to Marulan (35) 330 kV. See 6.2.2.
NSW 500 kV - remaining 35 converted to 5A6	26 August 2010	NSW	Remaining section of Marulan to Mt Piper (35) 330 kV line cut into Bannaby and recommissioned as Bannaby to Mt Piper (5A6) 500 kV. See 5.2.2.
Ross to Strathmore (880) 275 kV line decommissioned	16 September 2010	Queensland	CQ-NQ augmentation Stage 3. See 6.2.1.
Ross to Strathmore (8858) 275 kV line	16 September 2010	Queensland	CQ-NQ augmentation Stage 3. See 5.2.1.
Ross to Strathmore (8857) 275 kV line	30 September 2010	Queensland	CQ-NQ augmentation Stage 3. See 6.2.1.

6.2.1 Queensland Central to North augmentation

In September 2010 Powerlink completed the third stage of their project to increase the transmission capacity from central Queensland to north Queensland (CQ-NQ). Each of the three stages involved the construction of a new double-circuit 275 kV line and then pairing of the existing 275 kV lines. The first stage, between Broadsound and Nebo, was completed in May 2009 with the second stage, between Nebo and Strathmore, in August 2009. The third stage of this project, from

Ross to Strathmore, was completed in September 2010 and this relieved the thermal limits between Ross and Strathmore[1] that were introduced after the completion of stage 2.

6.2.2 NSW western 500 kV

2010 saw the completion of the NSW western 500 kV upgrade project. The Bayswater to Mt Piper (73 & 74) and Mt Piper to Marulan (35 & 36) lines were originally designed to operate at 500 kV but were initially run at 330 kV. In 2009 TransGrid progressively re-commissioned both Bayswater to Mt Piper lines to operate at their design voltage of 500 kV. Additionally Bayswater unit 4 was transferred to the new 500 kV bus at Bayswater.

In 2010 the Bannaby substation was cut into both the existing Sydney West to Yass (39) line and the Mt Piper to Marulan lines. Following that the Mt Piper to Marulan lines were upgraded to operate at 500 kV and Bayswater unit 3 was moved onto the 500 kV bus.

Each stage required updates to many of the NSW system normal thermal overload constraint equations.

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 2010 per month. Both Figure 3 and Figure 4 are cumulative area graphs so the 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 that was loaded into the database in late 2008 is included in the 2008 results and not the 2009 results.

[1] http://www.powerlink.com.au/asp/index.asp?sid=5056&page=Projects/northern&cid=5274&gid=407

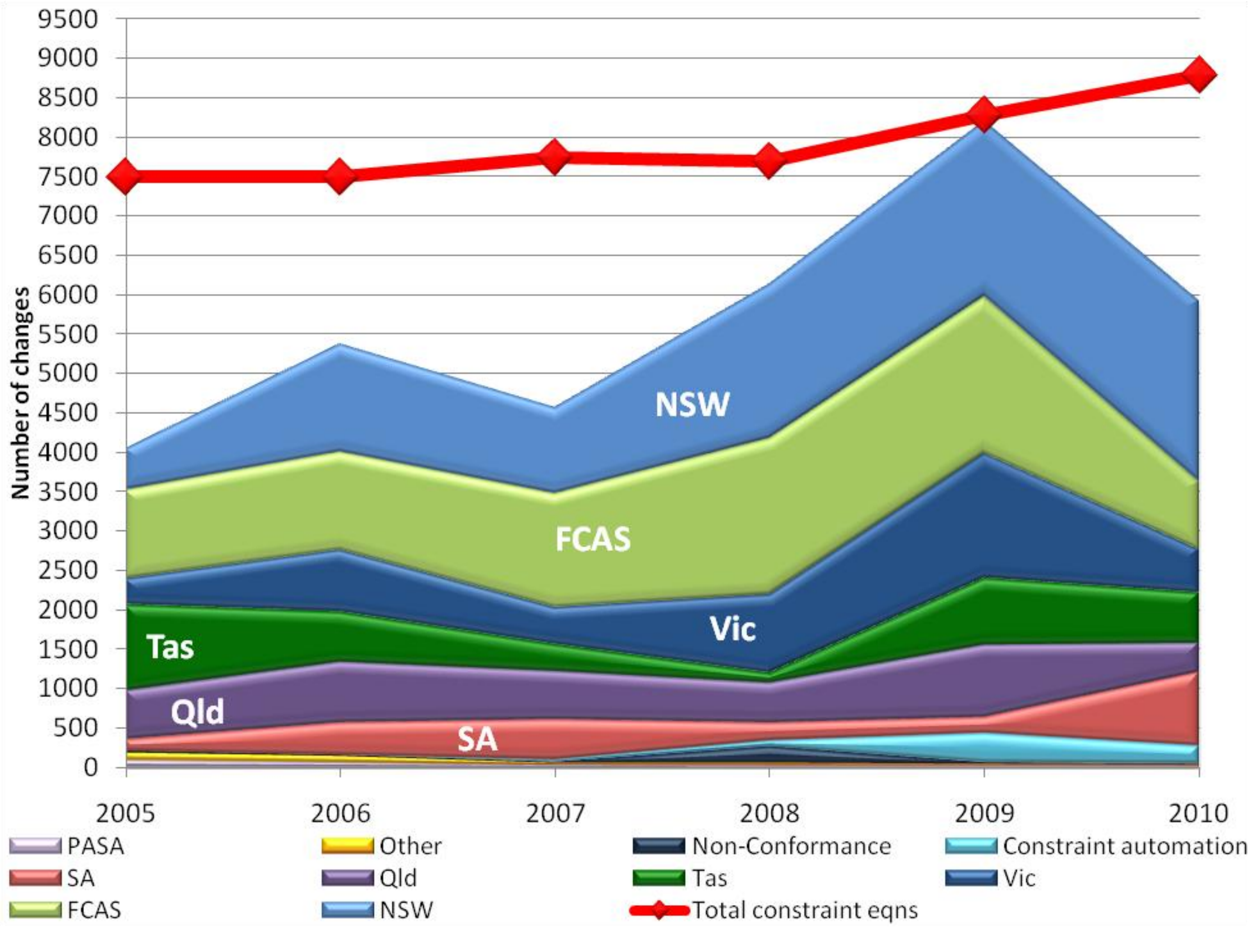

Figure 3: Constraint equation changes per calendar year

As can be seen from Figure 3 the number of constraint changes has steadily increased between 2007 and 2009 but fell in 2010. The 2008 results include all the changes associated with the Snowy region abolition and the spike in 2006 is due to the program to convert constraint equations to “fully co-optimised”. The number of changes in 2011 is not expected to be as high as 2010 due to the lower number of transmission changes proposed for 2011 and none involve multiple stages like the NSW western 500 kV project.

Figure 4 shows the constraint equation changes per month in 2010 and most regions had bursts of activity, although there was a steady amount of work in NSW and South Australia. The major groups of constraint changes (apart from those that are due to the generation and transmission changes in Table 1 & Table 2) can be attributed to the following:

- A number of Tasmanian FCAS constraint equations were changed to include the units at risk on the left hand side (LHS) (see constraint formulation guidelines section 8.7[2])
- The FCAS spike in March was due to updating constraint equations that set the FCAS service to zero. The number of changes is large as there can be up to 8 services for each unit.
- In April and May a review of all the South Australian thermal overload constraint equations was conducted
- In December a number of FCAS constraint equations had their limit types updated. These were originally indicated as “FCAS” but were modified to be “Unit Zero – FCAS”

[2] http://www.aemo.com.au/electricityops/170-0040.html

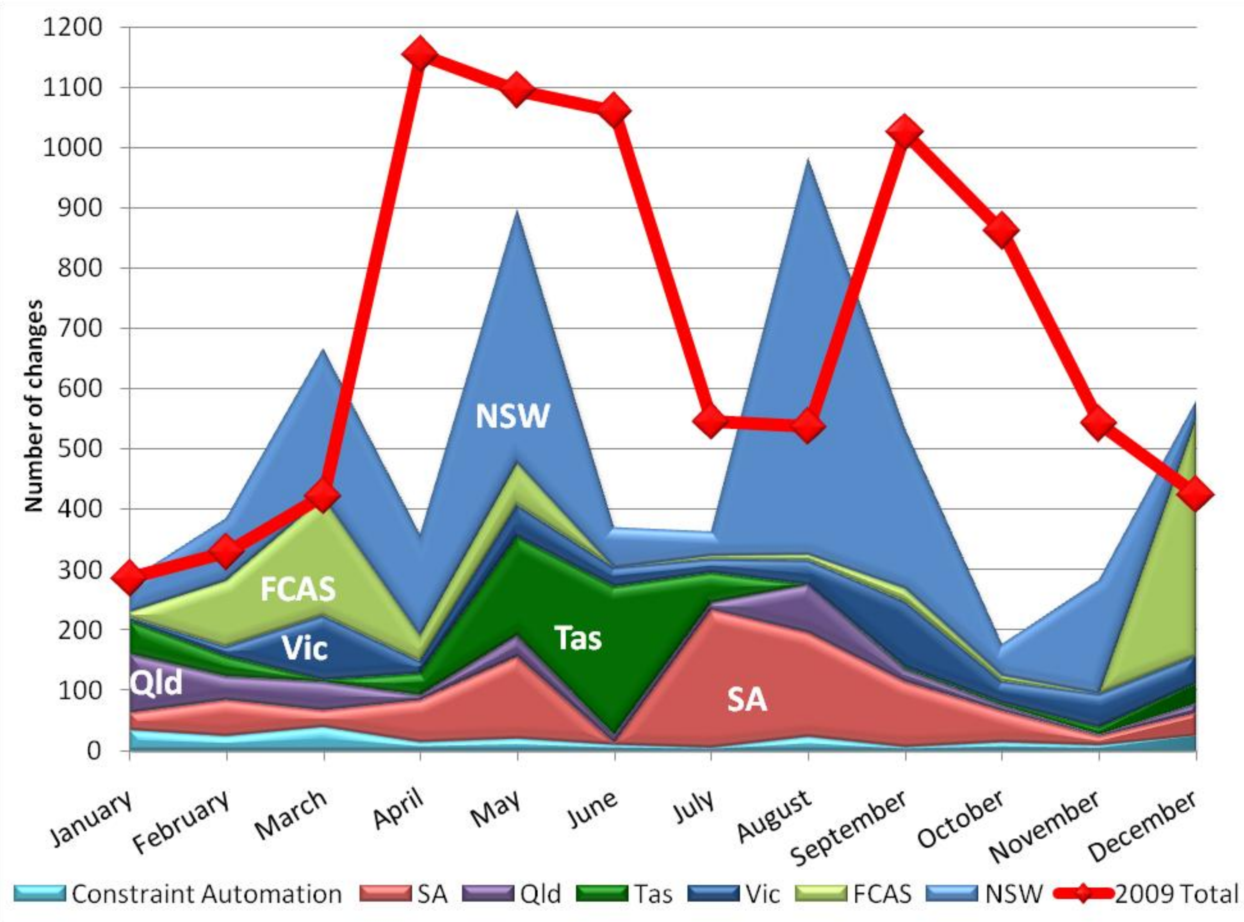

Figure 4: Constraint equation changes per month in 2010

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 2009 (if any) is indicated in brackets below the 2010 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 is required then this can be obtained from either the plain English converter[3] on the MMS web portal or via the MMS data model[4].

7.1 Binding constraint equations

When a constraint equation is binding it is either on its thermal or stability limit or setting the FCAS requirements. 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 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 some cases the binding results for several constraint equation IDs have been combined. This is due to some limits being split into 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)

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

- 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)

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 (2009)	*DESCRIPTION* / NOTES
V_T_NIL_FCSPS	1191 (3967)	*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. Although it bound for fewer hours in 2010 than 2009 it is still expected this will bind for a large amount in 2011.
N_X_MBTE2_A & N_X_MBTE2_B	1175 (80)	*Out = two Directlink cables* Two of the Directlink cables were out for a large period of 2010 (121 days – see section 10) compared to 2009 (11.4 days).
Q:N_NIL_BCK2L-G	615 (75)	*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.
V^^S_NIL_NPS_SE_OFF & V^^S_NIL_NPS_SE_ON & V^^S_TBCP_NPS_SE_OFF & V^^S_TBCP_NPS_SE_ON	577 (669)	*Out = Nil, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off, Tailem Bend capacitor bank on/off* There are 4 constraint equations that make up the voltage stability limit from Victoria to South Australia and the binding results from all these have been combined. It is expected this group of constraint equations will bind for a similar number of hours in 2011.
V::N_NILVxxx & V::N_NILQxxx	544 (223)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang line* There are 12 constraint equations that make up the transient stability export limit from Victoria and all the binding results have been combined. In 2009 these constraint equations bound for fewer hours (223), however, this was due to the major outage of the South Morang series capacitors (due to the Victorian bushfires in Feb 2009). The constraint equations for the outage of the South Morang series capacitors bound for 459 hours in 2009.
N_MBTE1_B	480 (128)	*Out = one Directlink cable* One of the Directlink cables was out for a significant period of 2010 (243 days – see section 10) compared to 2009 (142.6 days).
Q>>NIL_855_871	470 (334)	*Out = Nil, avoid overload on Calvale to Wurdong (871) line on trip of Calvale to Stanwell (855) line* This constraint equation is expected to bind for a similar amount in 2011 and for the next several years until Powerlink constructs double circuit 275kV lines between Calvale and Stanwell in 2012/13[5].
V>>N-NIL_HA	461 (40)	*Out = Nil, avoid overload on Murray to Upper Tumut (65) line on trip of Murray to Lower Tumut (66) line*

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
		This constraint equation binds for high flows from Victoria to NSW and most of the hours were accumulated in November and December 2010 (see Figure 5).
N_X_MBTE_3A & N_X_MBTE_3B	342 (140)	*Out= all three Directlink cables* All three of the Directlink cables were out for a longer period in 2010 (14.15 days – see section 10) compared to 2009 (5.7 days).
Q:N_NIL_OSC	312 (17)	*Out = Nil, Queensland to NSW oscillatory stability limit* This constraint equation sets the upper limit from Queensland to NSW at either 1078 or 950 MW (if one Millmerran generator is out of service). It bound at 950 MW for 92 hours in 2010. AEMO is investigating whether the 950 MW limitation can be removed and this work is expected to be completed in early 2011. 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.
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	311 (498)	*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 2011.
T_TAMARCCGT_GCS	294 (294)	*Limit output of Tamar Valley Power Station based on load available for shedding by Tamar Valley 220 kV generation control scheme (GCS)* This constraint equation was only introduced in August 2009 and yet it bound for a similar number of hours in 2010 despite it being active for over twice the timeframe. 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 2011.
V^^S_PACP_NPS_SEOFF & V^^S_PACP_NPS_SEON	270 (0)	*Out = One Para capacitor, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off* This constraint equation was new in 2010 and the capacitor bank was out for 49 days (see Table 19). It Is likely that these outages have contributed to the lower number of binding hours on the system normal voltage collapse constraint (V^^S_NIL_NPSxxx) in 2010.
Q>NIL_TR_TX1_4	261 (0)	*Out = Nil, avoid overloading a Tarong 275/132 kV transformer (#1 or #4) on trip of the other Tarong 275/132 kV transformer (#1 or #4)* This constraint equation was first invoked in late 2009 and started binding with the commissioning of the Condamine Power Station. It is expected to continue to bind until the commissioning of the Columboola to Western Downs 275 kV line in 2014[6].
Q:N_NIL_BI_POT	252 (39)	*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.
S_NBH_0	242 (0)	*Discretionary upper limit for North Brown Hill generation of 0 MW* This constraint equation was invoked prior to the North Brown Hill wind farm starting commissioning.
#BLOWERNG_E	239 (4)	*Quick constraint equation to limit Blowering to 40 MW* This constraint equation was invoked for the commissioning of a new

[6] http://www.powerlink.com.au/asp/index.asp?sid=5056&page=Projects/southern&cid=5276&gid=624

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
		excitation system at Blowering Power Station. The constraint set was invoked from 16th September 2009 through to 11th November 2010.
Q_N_NIL-1078 & Q>N_NIL_8L_8M	216 (11)	*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 for flows greater than 1105 MW. It was relabelled in late 2010 to better reflect its purpose as it is not a thermal overload constraint equation.
S>>V_NIL_SETX_SETX	214 (71)	*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.
N>N-NIL_MBDU	208 (60)	*Out = Nil, avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the other Mullumbimby to Dunoon line (9U7 or 9U6)* Either this constraint equation or N>N-NIL_LSDU (which bound for 147 hours in 2009 and 7 in 2010) are expected to bind for similar amounts in 2011 unless all 3 cables of Directlink are out of service for an extended period of time.

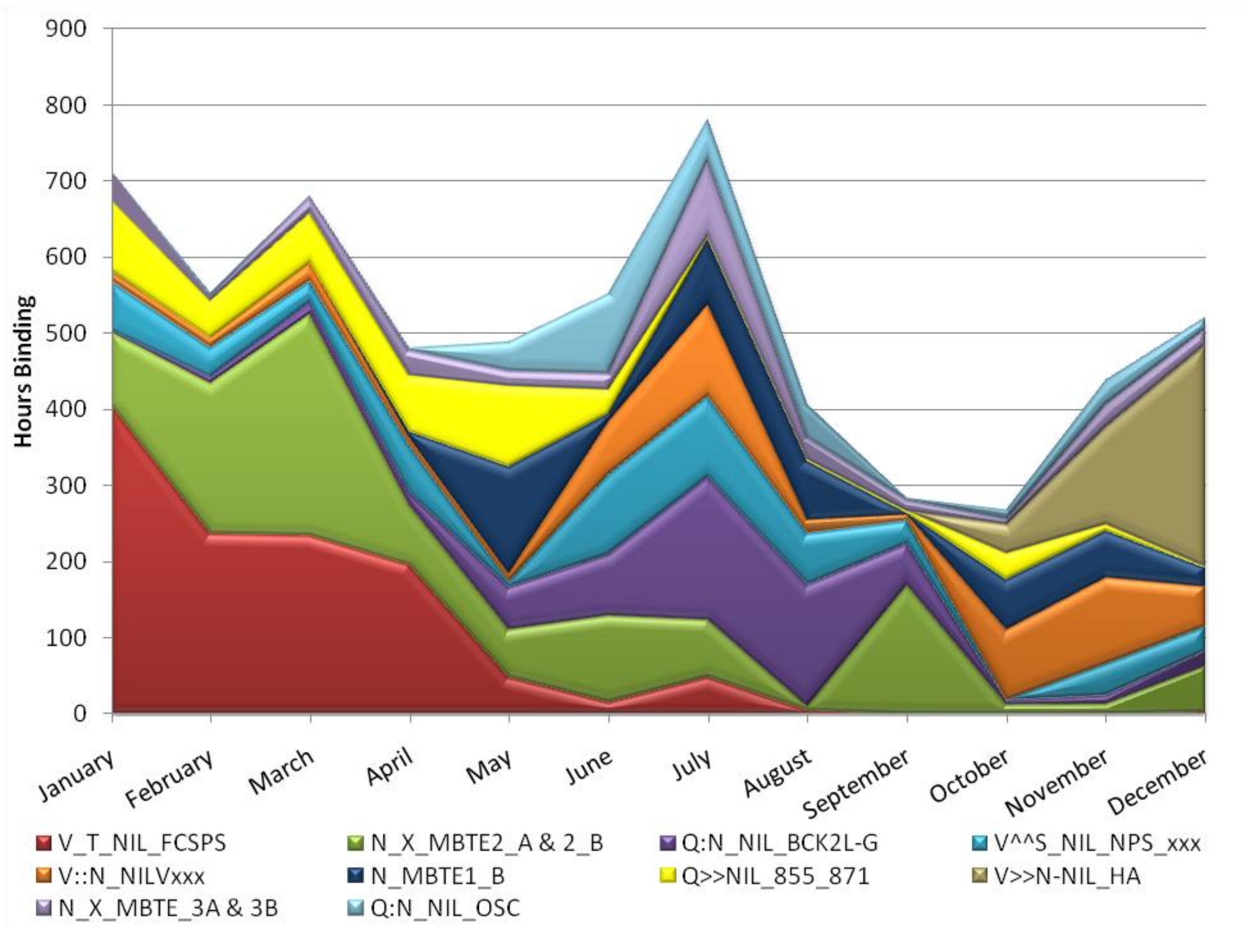

Figure 5: Top 10 binding constraint equations per month

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 (2009)	*DESCRIPTION* / NOTES
F_I+NIL_MG_R5	7945 (7707)	*NEM raise 5 minute requirement for a NEM generation event* The largest unit is usually Kogan Creek or one of the NSW 660MW units.
F_I+NIL_DYN_LREG	7861 (7535)	*NEM lower regulation requirement*
F_I+NIL_MG_R6	7501 (7738)	*NEM, raise 6 second requirement for a NEM generation event*
F_I+NIL_MG_R60	7356 (7444)	*NEM raise 60 second requirement for a NEM generation event*
F_I+ML_L5_0400	5939 (6099)	*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	3963 (5249)	*Tasmania raise 6 second requirement for loss of Basslink, FCSPS available* These were changed from a single constraint equation into 4 constraint equations due to the regression analysis done as part of the 2009 Tasmanian frequency operating standards change and the binding results for these have been combined.
F_T+NIL_BL_R60_1 & F_T++NIL_BL_R60_x	3020 (4844)	*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_I+ML_L6_0400	2603 (4714)	*NEM lower 6 second requirement for a NEM load event* See note on F_I+ML_L5_0400
F_T++NIL_TL_L60	2237 (1137)	*Tasmania lower 60 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_MAIN++NIL_BL_L60	1955 (3335)	*Mainland lower 60 second requirement for loss of Basslink, Basslink flow into Tasmania, Basslink able to transfer FCAS*
F_T++NIL_TL_L6	1736 (183)	*Tasmania lower 6 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_MAIN++ML_L6_0400	1580 (488)	*Mainland lower 6 second requirement for a mainland load event, Basslink able transfer FCAS* See note on F_I+ML_L5_0400
F_I+ML_L60_0400	1484 (1110)	*NEM lower 60 second requirement for a NEM load event* See note on F_I+ML_L5_0400
F_T+NIL_BL_R5	1241 (4530)	*Tasmania raise 5 minute requirement for loss of Basslink, FCSPS available*
F_I+APHY_L5	1220 (451)	*Out = Alcoa Portland to Heywood line, NEM lower 5 minute requirement for the loss of the remaining line* One of the two Heywood to Alcoa lines were out of service for 71.3 days in 2010 (versus 33.9 days in 2009) - see Table 19.

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
F_MAIN++NIL_MG_R60	1162 (789)	*Mainland raise 60 second requirement for a mainland generation event, Basslink able transfer FCAS*
F_MAIN++ML_L5_0400	1161 (1517)	*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_MIG_R5	954 (621)	*Tasmania raise 5 minute requirement for a Tasmania generation event (loss of the largest inertia), Basslink able to transfer FCAS*
F_T++RREG_0050	939 (742)	*Tasmania raise regulation requirement greater than 50 MW, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R6	817 (515)	*Mainland raise 6 second requirement for a mainland generation event, Basslink able transfer FCAS*

7.1.3 Binding trends

Figure 6 and Figure 7 show the binding constraint equations categorised by both region and type for the past 5 years. The trends indicated by these two graphs are:

- More constraint equations are binding in NSW (580 hours in 2005 versus 3283 hours in 2010) and Tasmania (1152 hours in 2005 and 1534 in 2010)
- Binding constraint hours are decreasing in all other regions
- Thermal, voltage stability and transient stability constraint equations are binding more
    - Thermals have increased from 3151 hours in 2005 to 5134 hours in 2010
    - Transient stability has increased 911 hours in 2006 to 2289 hours in 2010
    - Voltage stability has increased from 512 hours in 2008 to 1307 hours in 2010
- Binding hours due to outages of Directlink cables have increased from 238 hours in 2006 to 1997 hours in 2010
- The use of discretionary and quick constraint equations has significantly decreased since 2005.

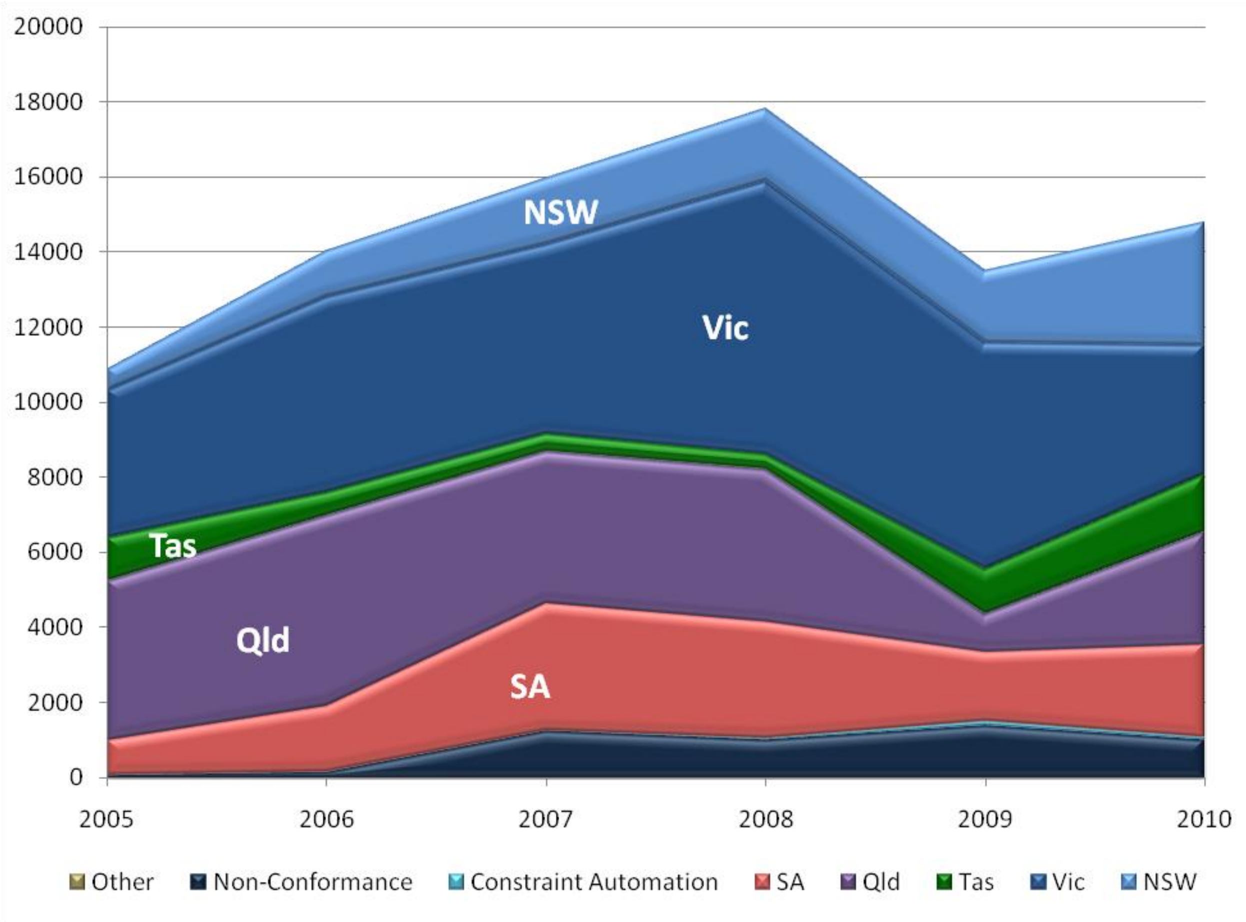

Figure 6: Binding constraint equations by region

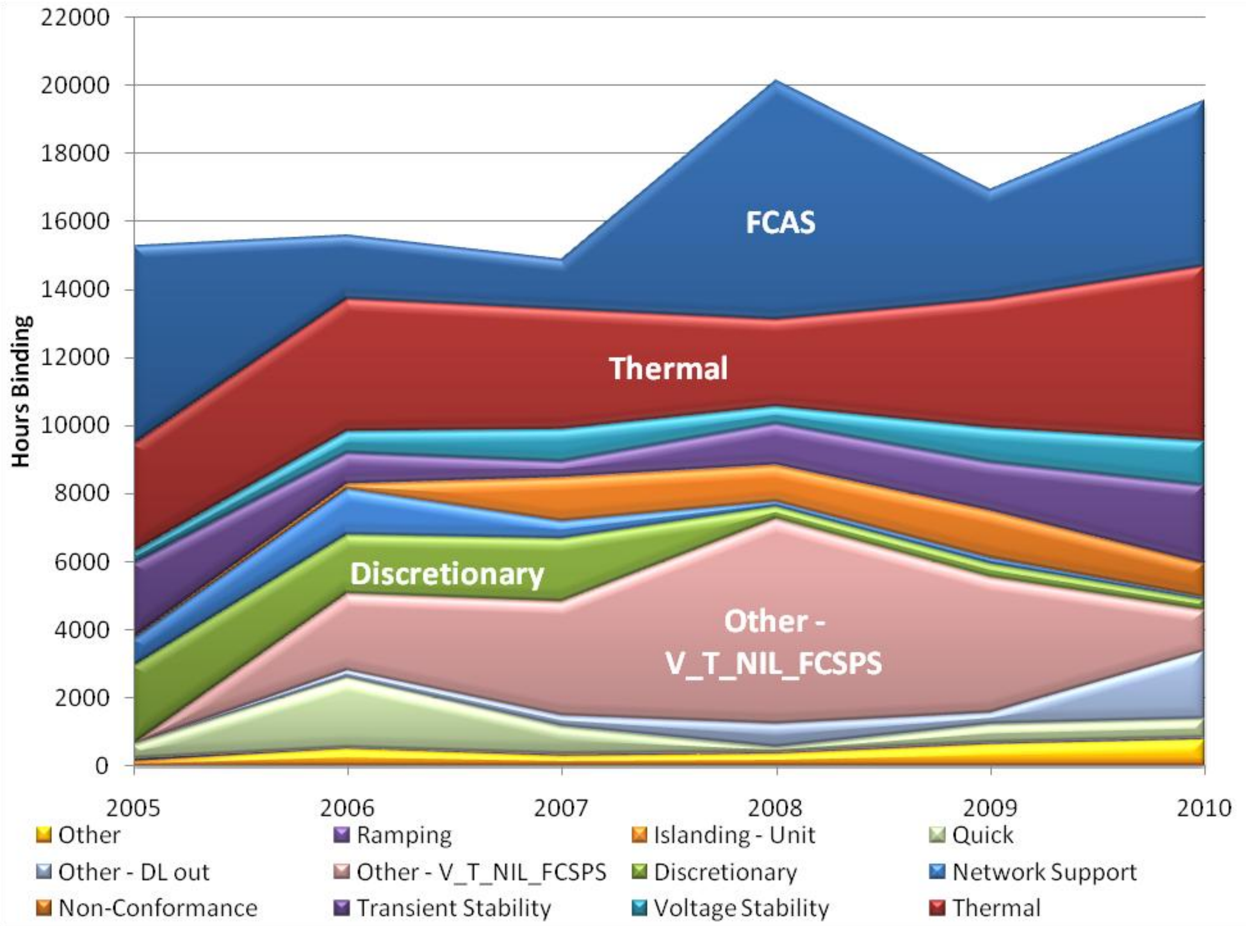

Figure 7: Binding constraint equations by limit type

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 (2009)	*DESCRIPTION* / NOTES
#VIC1-NSW1_E_E	6.50 (0)	*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 21st April, 22nd April and 22 June 2010. 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.
T^T_NIL_BL_5_DS	5.33 (1.58)	*Out = Nil, Palmerston 110 kV bus not split, avoid voltage instability for loss of a Liapootah to Cluny Tee to Chapel St line* On 18th October 2010 the constraint equation violated as an incorrect status point was being used. This status point should have indicated whether the southern system special protection scheme (SSSPS) control scheme in southern Tasmania was activated or not. On this day the scheme was activated but the status point used in the constraint equation continued to indicate the SSSPS was not active. The constraint equation has since been modified to use the correct status point.

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
		In all other cases this constraint equation violated due to fast load increases and the capacitor bank switching not keeping up.
T>T_FASH_1_2_F1	5.08 (0)	*Out = Farrell to Sheffield No.1 or 2 line, Farrell 220 kV bus split, limit Tribute and Mackintosh <= 110% of West Coast load* The constraint equation was setting a limit below the Band 1 bid for Tribute. Tribute's bid was 55 MW versus approximately 40 MW from the constraint equation.
Q>GBMU_GBMU_MDSPT	4.08 (0)	*Out = Greenbank to Mudgeeraba (835 or 836) line, avoid overloading Molendinar to Southport (F907) line on trip of remaining Greenbank to Mudgeeraba (835 or 836) line* This constraint equation violated during a concurrent outage in NSW of the Koolkhan to Lismore (967) line. Additionally there was a mismatch of 25 MW between SCADA and RTNET (where AEMO's contingency analysis is performed) on the in-service Greenbank to Mudgeeraba (526) line.
N>N-KKLS_TE_1	3.33 (0.17)	*Out = Koolkhan to Lismore (967) line, avoid overloading Tenterfield to Lismore (96L) on trip of Coffs Harbour to Lismore (89) line* On the 23rd and 24th March 2010 the violations were due a concurrent outage of 2 cables of Directlink. On the 1st and 2nd June 2010 this constraint equation was violating concurrently with Q>GBMU_GBMU_MDSPT (see note above).
N_X_MBTE2_B	2.67 (0.08)	*Out = two Directlink cables, Queensland to NSW limit* Also see Table 3 for comments. In these instances, the constraint equation was violating against a ramping constraint equation.
Q>NIL_SMRS_SMRS	2.17 (0.75)	*Out = Nil, avoid overloading Strathmore to Ross (879) line on trip of Strathmore to Ross (8858) line* Each time the constraint equation bound it was using a default rating and Powerlink advised real time ratings which cleared the violation. With the commissioning of the new Strathmore to Ross lines (see 6.2.1) this constraint equation has been archived.
NC_S_LKBONNY2	2.08 (5.08)	*Non conformance constraint for Lake Bonney 2 wind farm*
T>T_FASH_1_2_D1	1.67 (0)	*Out =Farrell to Sheffield No.1 or 2 line, Farrell 220 kV bus split, limit Reece 1 and Mackintosh <= 110% of West Coast load* The violation was caused by a Reece machine being on the technical limits of the lower regulation trapezium thereby preventing the dispatch engine from setting a lower dispatch target. The cause was due to vibration issues with the No. 1 Reece machine that did not allow it to operate below 40MW. Following further discussions, Hydro Tasmania were able to run the unit at 35 MW as long as there were no vibration alarms.
S>NIL_NOTI_NOTI	1.67 (0)	*Out = Nil, avoid overloading a Torrens Island to New Osborne 66 kV line for trip of another Torrens Island to New Osborne 66 kV line* This constraint equation violated as Quarantine 5 was targeted below its band 1 offer MW. The violation was managed by ElectraNet agreeing to offload the remaining New Osborne to Torrens Island 66 kV transmission line on the trip of the remaining New Osborne to Torrens Island 66 kV line.
NSA_V_BDL02_20	1.67 (1.42)	*Bairnsdale Unit 2 >= 20 MW for network support agreement*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
#SA1_E_20100422	1.58 (0)	*Quick constraint equation applied to V-SA and Murraylink (from Victoria to SA) at 0 MW* On 22nd April this constraint equation was invoked to manage negative residues.
S>SE132CB_SETX_SGKH	1.42 (0)	*Out = South East CB6160 or CB6162, avoid overloading Snuggery to Keith line on trip of a South East 275/132 kV transformer* The majority of violations (15 dispatch intervals) were on 20th August 2010. This constraint equation has 3 units on the LHS: Lake Bonney 2, Lake Bonney 3 and Snuggery. When the constraint equation was invoked only one unit, Lake Bonney 2, was online. The violations persisted as Lake Bonney 2 had a 1 MW / 5 minute rate of change down.
Q_RS_260	1.33 (0)	*Ross cut-set discretionary upper limit of 260 MW* On 21st March 2010 this constraint equation was invoked for the reclassification of loss of both Strathmore to Ross (879 and 880) lines as a credible contingency. As only 2 generators on the LHS were online at the time of invocation the constraint equation violated until the Yabulu #1 GT was on line.
N>N-NIL_TE_E1	1.33 (0)	*Out = Nil, avoid overloading Armidale to Coffs Harbour (96C) on trip of Armidale to Coffs Harbour (87) line* This constraint equation either violated due to a concurrent outage of 2 or 3 Directlink cables or rate of change limit (QNTE_ROC constraint equation).
CA_BPS_3B883491_01	1.25 (0)	*Constraint automation, avoid overloading Snuggery to Blanche line for loss of a South East 275/132 kV transformer* The loss of the South East transformer split the bus at South East and opened the Snuggery to South East line. The constraint automation built constraint equation did not model this correctly and violated. The constraint builders provided a new constraint equation, S>SECB6161_SETX_SGBL, to resolve the violations.
S>BGPA_BRPA_MNWT	1.25 (0)	*Out = Bungama to Para line, avoid overloading Mintaro to Waterloo line for trip of Brinkworth to Para line* The violations were due to the Mintaro generator being online (which has a factor of 1 on the LHS) and non-conformance of other units on the LHS such as Northern, Playford and Hallett (noting that it has the lowest LHS factor of 0.097).
NC_V_BDL02	1.75 (0.08)	*Non conformance constraint for Bairnsdale 2 power station*
Q^FNQ_-030	1.08 (0)	*Out = Ross SVC, far north Queensland voltage stability limit for loss of either Chalumbin to Ross (857 or 858) line* This constraint equation was invoked for an outage of the Ross SVC. Not enough units were generating and able to relieve the violation so AEMO directed on Barron Gorge and Kareeya to a total of 50 MW (via constraint equation #QLD1_E_20100117).
Q>NIL_SMRS_CRTVS2	1.00 (0)	*Out = Nil, avoid overloading Clare South to Townsville South (7131) line on trip of Strathmore to Ross (8858) line* Similar to Q>NIL_SMRS_SMRS this constraint equation was using a default rating and Powerlink provided a real time rating which cleared the violation. With the commissioning of the new Strathmore to Ross lines (see 6.2.1) this constraint equation is no longer required. Powerlink now provides a dynamic rating for the Clare South to Townsville South (7131) line.

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 2009 is indicated in brackets below the 2010 hours. The 2009 summated marginal values are indicated in brackets below the 2010 hours. The top 20 market impact constraint equations for 2009 are in Table 20 in Appendix 1.

The constraint equations S_NBH_0, S_HALWF_0, S_PLN_ISL1 and S_PLN_ISL2 have large summated marginal values in Table 6. These four constraint equations set an upper limit of zero MW on the generators on the LHS and are either invoked for commissioning of 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 2010

EQUATION ID (SYSTEM NORMAL BOLD)	Σ MARGINAL VALUES	HOURS (2009)	*DESCRIPTION* / NOTES
Q>NIL_TR_TX1_4	$3,250,963 (0)	261.0 (0)	*Out = Nil, avoid overloading a Tarong 275/132 kV transformer (#1 or #4) on trip of the other Tarong 275/132 kV transformer (#1 or #4)* See Table 3 for comments
S_NBH_0	$2,948,721 (0)	241.5 (0)	*Discretionary upper limit for North Brown Hill generation of 0 MW* See Table 3 for comments
S_PLN_ISL1	$1,716,792 ($408,637)	14.3 (3.6)	*Out = Whyalla to Yadnarie line, Port Lincoln units 1 and 2 islanded*
Q>NIL_CNTR_CNTR	$1,333,214 (0)	107.5 (0)	*Out = Nil, avoid exceeding the Ergon relay limit on a Chinchilla to Tarong line for the trip of the remaining Chinchilla to Tarong line* See comments on Q>NIL_TR_TX1_4 in Table 3
N>>N-NIL__S	$1,232,109 ($1,198,350)	34.8 (36.6)	*Out= Nil, avoid overloading Mt Piper to Wallerawang (70) line on trip of Mt Piper to Wallerawang (71) line* This constraint equation bound heavily in late 2009 and early 2010 due to the outage of a Wallerawang unit. The constraint equation was introduced in August 2009 with the commissioning of 70 line and it replaced N>>N-NIL__E. AEMO and TransGrid agreed to an operational arrangement to reduce the time this constraint equation bound. In August 2010 TransGrid completed changes which increased the rating to the point where this constraint equation would bind rarely (if at all) into the future.
Q>NIL_TRCN_TRCN	$1,056,628 ($198,176)	86.5 (16.3)	*Out = Nil, avoid exceeding the Powerlink relay limit on a Tarong to Chinchilla line for the trip of the remaining Tarong to Chinchilla line* See comments on Q>NIL_TR_TX1_4 in Table 3
T_T_FASH1_B_2	$1,004,843 (0)	12.6 (0)	*Out = Farrell to Sheffield No.1 or 2 line, Farrell 220 kV bus split, limit John Butters + Mackintosh >= 90% of West Coast load*

F_T+NIL_BL_R6_1 & F_T++NIL_BL_R6_x	$925,299 ($2,508,345)	3,963 (5,376)	*Tasmania raise 6 second FCAS requirement for loss of Basslink, FCSPS available* See Table 4 for comments
S>BGPA_BRPA_MNWT	$699,998 (0)	12.3 (0)	*Out = Bungama to Para line, avoid overloading Mintaro to Waterloo line for trip Brinkworth to Para line*
V^^S_NIL_NPS_xxx & V^^S_TBCP_NPS_xxx	$554,701 ($2,464,858)	576.6 (668.5)	*Out = Nil, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off, Tailem Bend capacitor bank on/off* See Table 3 for comments
S_PLN_ISL2	$536,971 (0)	4.2 (0)	*Out = Yadnarie to Port Lincoln line Port Lincoln units 1 and 2 islanded*
F_S++HYML_L60	$516,002 ($27,149)	72.3 (59.0)	*Out = one Heywood to Moorabool line or one Moorabool to Sydenham line, SA lower 60 second FCAS requirement*
V^SML_NSWRB_2	$490,102 ($1,815,493)	25.3 (60.7)	*Out = NSW Murraylink runback scheme, avoid voltage collapse for trip of Darlington Point to Buronga (X5) 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>NIL_NIL_MNWT	$460,216 ($869,406)	5.1 (15.2)	*Out = Nil, avoid overloading Mintaro to Waterloo line for no contingencies*
N>>V-X_DDH2_DDSM_2	$417,285 (0)	5.1 (0)	*Out = Dederang (H2) 330/220 kV transformer and one Dederang to South Morang line, avoid overloading Dederang (H1) 330/220 kV transformer on trip of the remaining Dederang to South Morang line*
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	$404,551 ($79,662)	61.8 (114.6)	*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.
S_HALWF_0	$385,657 (0)	31.5 (0)	*Discretionary upper limit for Hallett wind farm generation of 0 MW*
F_S++HYML_L6	$372,685 ($20,526)	16.3 (32.2)	*Out = one Heywood to Moorabool line or one Moorabool to Sydenham line, SA lower 6 second FCAS requirement*
V>>V_NIL_1B	$341,207 ($290,496)	76.8 (16.4)	*Out = Nil, avoid overloading Dederang to Murray No.2 line for loss of the parallel No.1 line, 15 minute line ratings*
V>>SML_DDGN	$338,835 (0)	4.3 (0)	*Out = Dederang to Glenrowan No.1 or No.3 line, avoid overloading Dederang to Shepparton line on trip of Dederang to Glenrowan No.3 or No.1 line*

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 included on the secondary axis is the number of hours the interconnector target was at each flow level (binding or not binding).

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_TE_1 and N>N-CHLS_TE_A1) should be relieved with the construction of the Dumaresq to Lismore 330kV line in 2014[7]. In 2010 the majority of the flow on Terranora is restricted by outages of one or more Directlink cables (see Figure 9).

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

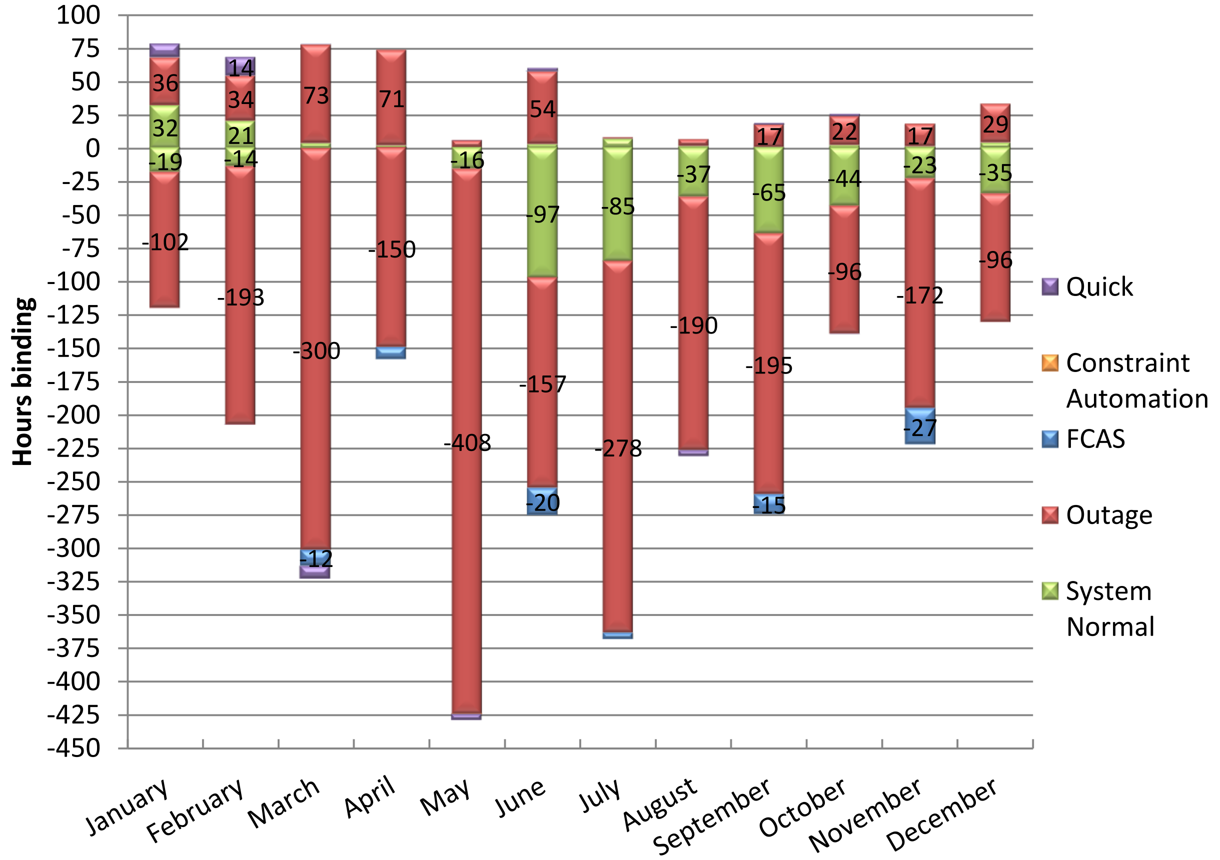

Figure 8: Categorized binding intervals per month for N-Q-MNSP1

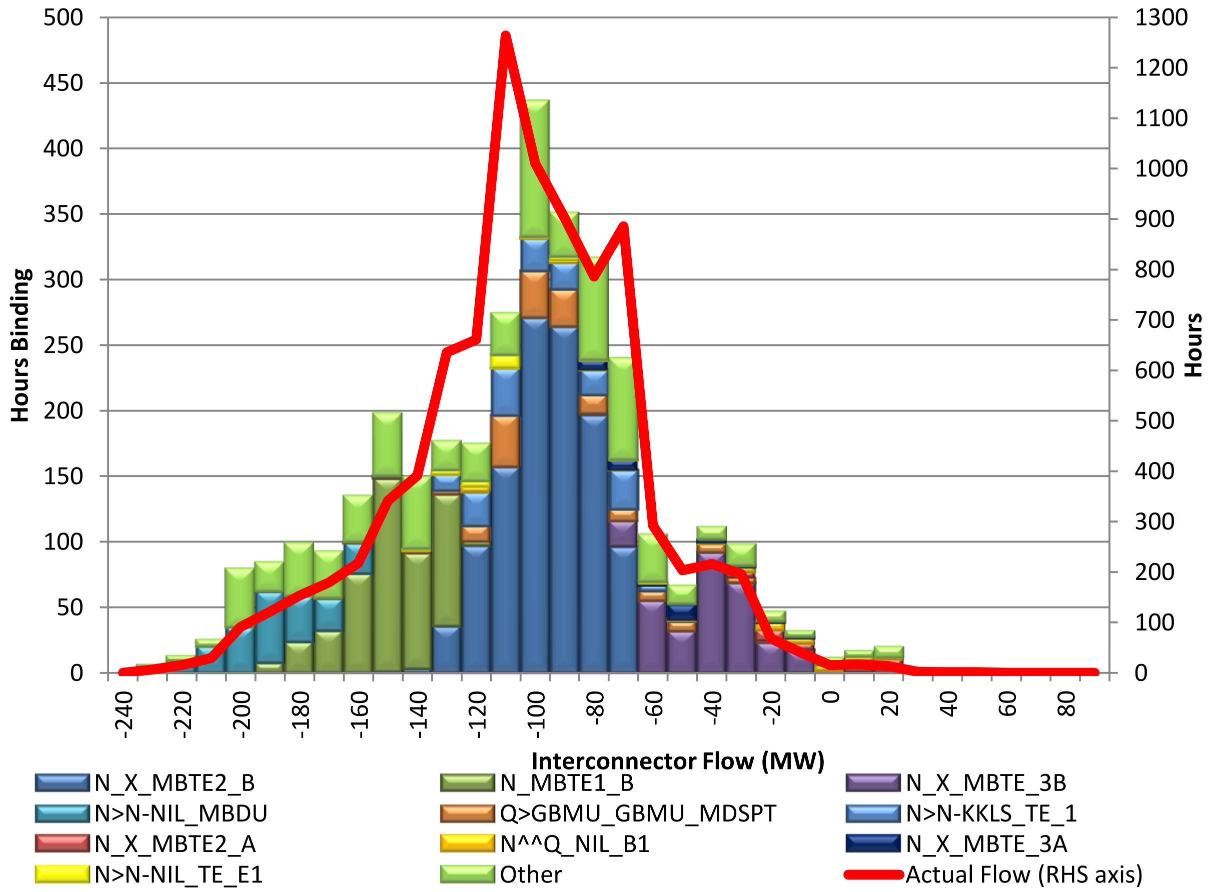

Figure 9: Binding constraint equation distribution for N-Q-MNSP1

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
N>N-KKLS_TE_1	173.5 (207.0)	*Out = Koolkhan to Lismore (967), avoid overloading Tenterfield to Lismore (96L) line on trip of Coffs Harbour to Lismore (89) line* The 967 line was out for a total of 25.4 days in 2010 (see Table 19). The 96L line is the weaker of the 2 lines into Lismore from the south and support is usually required from Terranora interconnector. It is expected that this constraint equation will continue bind for a reasonable portion of any future outage times.
N_X_MBTE2_A	39.4 (8.4)	*Out = two Directlink cables* See Table 3 for comments
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	35.2 (64.1)	*Out= Nil, avoid voltage collapse on loss of the largest Queensland unit* See Table 6 for comments
N_X_MBTE_3A	30.6 (114.8)	*Out = all three Directlink cables* See Table 3 for comments.
N>N-NIL_TE_E1	22.3 (0.7)	*Out = Nil, avoid overloading Armidale to Coffs Harbour (96C) line on trip of Armidale to Coffs Harbour (87) line* The binding hours for this constraint equation are low due to the number of number outages on the 132 kV lines between Armidale and Lismore (in particular outages of 967 line) in 2009 and 2010.
N^N-89_LSTX_SVC	15.7 (0.5)	*Out = Coffs Harbour to Lismore (89) line and Lismore 330/132 kV transformer with Lismore SVC in reactive power control mode, avoid voltage collapse on trip of Koolkhan to Lismore (967) line*
N>N-CHLS_TE_A1	12.3 (15.1)	*Out = Coffs Harbour to Lismore (89) line, avoid overloading Tenterfield to Lismore (96L) line on trip of Koolkhan to Lismore (967) line*
#N-Q-MNSP1_I_E	12.2 (33.8)	*Quick constraint equation applied to Terranora at various levels* This quick constraint equation was invoked a number of times during 2010 to manage power system security, periods when the Directlink was unable to be controlled (due to a communication failure) and oscillations in dispatch targets across successive dispatch intervals.
NQTE_ROC	10.9 (22.2)	*Out = Nil, rate of change (NSW to Queensland) limit (80 MW / 5 minute) for Terranora interconnector*
N>N-ARKK_CH_CB892A	10.1 (0)	*Out = Armidale to Koolkhan (966) line with Coffs Harbour CB 892 opened, avoid overloading Armidale to Coffs Harbour (96C) line on trip of Armidale to Coffs Harbour (87) line*

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
N_X_MBTE2_B	1117.8 (70.4)	*Out = two Directlink cables* See Table 3 for comments
N_MBTE1_B	477.0 (125.1)	*Out = one Directlink cable* See Table 3 for comments
N_X_MBTE_3B	307.3 (20.6)	*Out = all three Directlink cables* See Table 3 for comments.

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
N>N-NIL_MBDU	206.9 (60.0)	*Out = Nil, avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the other Mullumbimby to Dunoon line (9U7 or 9U6)* See Table 3 for comments.
Q>GBMU_GBMU_MDSPT	176.6 (0)	*Out = Greenbank to Mudgeeraba (835 or 836) line, avoid overloading Molendinar to Southport (F907) line on trip of remaining Greenbank to Mudgeeraba (835 or 836) line*
N>N-EWMB_TE_B	137.1 (1.7)	*Out = Ballina to Lennox Head (8504) line, avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the remaining Mullumbimby to Dunoon line (9U7 or 9U6)* *The 8504 line was out for a total of 86 days in 2010 (see* Table 19*)*
N>N-NIL_DC	102.2 (10.1)	*Out = Nil, avoid overloading Armidale to Tamworth (86) line on trip of Armidale to Tamworth (85) line*
Q>NIL_757+758_B	69.0 (9.8)	*Out = Nil, avoid overloading a Mudgeeraba to Terranora (757 or 758) line on no contingencies*
F_Q++ARTW_L6	55.3 (12.1)	*Out = Armidale to Tamworth (85 or 86) line, Queensland lower 6 second FCAS requirement*
N>>N-NIL__S	32.0 (36.3)	*Out = Nil, avoid overloading Mt Piper to Wallerawang (70) on trip of Mt Piper to Wallerawang (71) line* See Table 6 for comments

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 Armidale to Tamworth (86) line in NSW as well as 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 flow was from Queensland to NSW for the majority of the time and only flows above 950 MW are heavily constrained (see Figure 11).

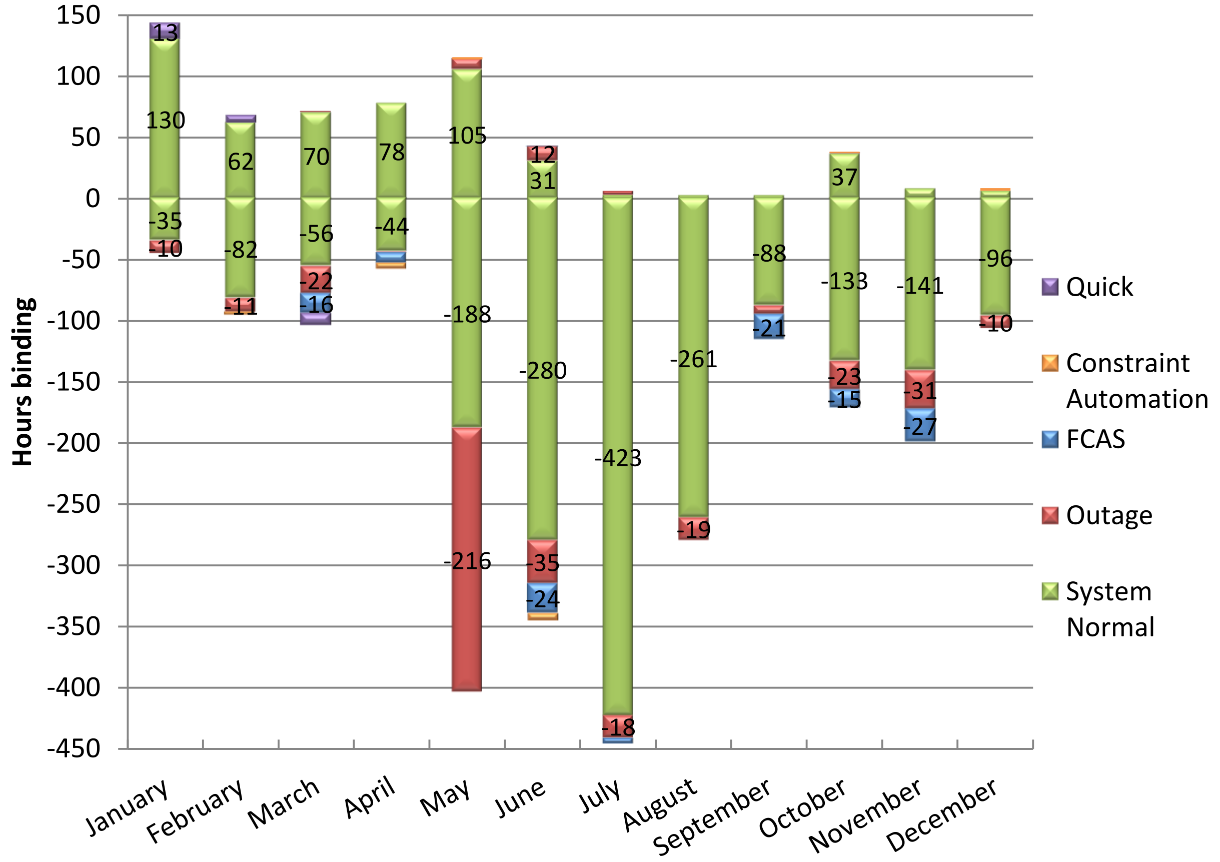

Figure 10: Categorized binding intervals per month for NSW1-QLD1

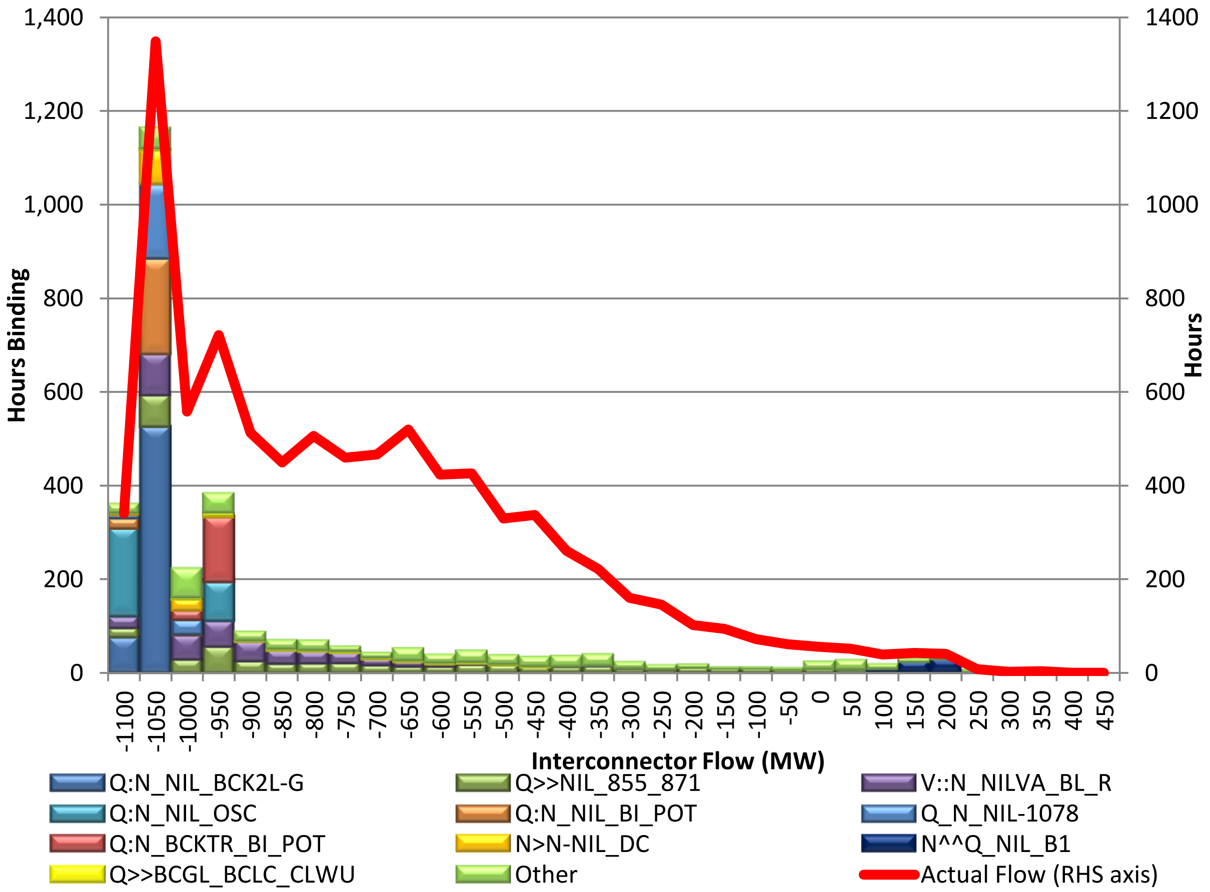

Figure 11: Binding constraint equation distribution for NSW1-QLD1

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
Q>>NIL_855_871	466.0 (327.3)	*Out = Nil, avoid overload on Calvale to Wurdong (871) line on trip of Calvale to Stanwell (855) line* See Table 3 for comments
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	60.2 (109.2)	*Out = Nil, avoid voltage collapse on loss of the largest Queensland unit* See Table 6 for comments
Q>>BCGL_BCLC_CLWU	18.3 (4.4)	*Out = Bouldercombe to Gladstone (812) line, avoid overloading Calvale to Wurdong (871) line on trip of Bouldercombe to Gladstone (811) line* The Bouldercombe to Gladstone (812) line was out for over 30 days (see Table 19).
#QLD1_E_20100212	5.9 (0)	*Quick constraint equation applied to NSW to Queensland on both Terranora and QNI at various levels* Invoked on 12th February 2010 to manage negative residues between NSW and Queensland.
#QLD1_E_20100122	5.3 (0)	*Quick constraint equation applied to NSW to Queensland transfers on both Terranora and QNI interconnectors at various levels* Invoked on 22nd January 2010 to manage negative residues between NSW and Queensland.
N::Q_NIL_Bx & N:Q_NIL_Bx	5.3 (7.3)	*Out = Nil, transient stability limit for fault on a Liddell to Newcastle (81) or Liddell to Tomago (82) line* The binding results from the 9 constraint equations that make up the transient stability export limit from NSW to Queensland have been combined. These constraint equations were replaced with new limits in September 2010: N::Q_NIL_KC, N::Q_NIL_TNT, N:Q_NIL_LDMU and N:Q_NIL_LDTW
Q>>812_CLWU_BCLC & Q>>BCGL_CLWU_BCLC	4.1 (0)	*Out = Bouldercombe to Gladstone (812) line, avoid overloading Bouldercombe to Larcom Creek (811) line on trip of Calvale to Wurdong (871) line* This constraint equation was renamed (to Q>>BCGL_CLWU_BCLC) in mid 2010 so the binding results for the two have been combined. The Bouldercombe to Gladstone (812) line was out for over 30 days (see Table 19).
Q>>NIL_871_855	3.8 (0)	*Out = Nil, avoid overload on Calvale to Stanwell (855) line on trip of Calvale to Wurdong (871) line* This was a new constraint equation in 2010. Normally post contingent loading on 871 line (Q>>NIL_855_871) is more constraining. However, on 17th October 2010 the rating for 871line increased at the same time the rating for 855 line decreased to the point where it became the constraining element (both ratings are dynamically calculated based on the current power system conditions). AEMO's control room used the constraint automation (constraint equation CA_BPS_3BCD0809_01) to manage the issue. It is expected that Q>>NIL_855_871 will continue to bind more frequently than Q>>NIL_871_855 in future.
#QLD1_E_20100123	3.5 (0)	*Quick constraint equation applied to NSW to Queensland transfers on both Terranora and QNI interconnectors at various levels* Invoked on 23rd January 2010 to manage negative residues between NSW and Queensland.
#QLD1_E_20100112	3.3 (0)	*Quick constraint equation applied to NSW to Queensland transfers on both Terranora and QNI interconnectors at various levels* Invoked on 12th January 2010 to manage negative residues between

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
		NSW and Queensland.

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
Q:N_NIL_BCK2L-G	599.3 (72.8)	*Out = Nil, avoid transient instability for a 2 phase to ground fault on a Bulli Creek to Dumaresq line at Bulli Creek* See Table 3 for comments
V::N_NILVxxx & V::N_NILQxxx	381.4 (79.7)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 3 for comments
Q:N_NIL_OSC	271.2 (16.0)	*Out = Nil, Queensland to NSW oscillatory stability limit* See Table 3 for comments
Q:N_NIL_BI_POT	226.3 (37.8)	*Out = Nil, avoid transient instability on trip of a Boyne Island potline (400 MW)* See Table 3 for comments
Q_N_NIL-1078 & Q>N_NIL_8L_8M	195.7 (10.3)	*Out= Nil, reduce QNI flow when it is over the 1078 MW limit by 1078 minus the MW over the 1078 MW limit (capped at 1000 MW)* See Table 3 for comments
Q:N_BCKTR_BI_POT	158.3 (4.0)	*Out = one line Bulli Creek to Tarong line (8814,8815, 9901, or 9902) or a Braemar transformer, avoid transient instability on trip of a Boyne Island potline (400 MW)* *The Braemar to Tarong (8814 or 8815) lines were out for a total of 14.5 days in 2010, see* Table 19.
N>N-NIL_DC	104.9 (11.8)	*Out = Nil, avoid overloading Armidale to Tamworth (86) line on trip of Armidale to Tamworth (85) line*
F_Q++ARTW_L6	53.6 (9.6)	*Out = Armidale to Tamworth (85 or 86) line, Queensland lower 6 second FCAS requirement*
V::N_HYMLxxx	46.0 (1.1)	*Out = Heywood to Moorabool line, avoid transient instability for fault and trip of a Hazelwood to South Morang 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 Heywood to Moorabool lines were out for 27.3 days in 2010 (compared to 17 days in 2009), see Table 19.
N>>N-NIL__S	34.6 (35.9)	*Out = Nil, avoid overloading Mt Piper to Wallerawang (70) line on trip of Mt Piper to Wallerawang (71) line* See Table 6 for comments

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.

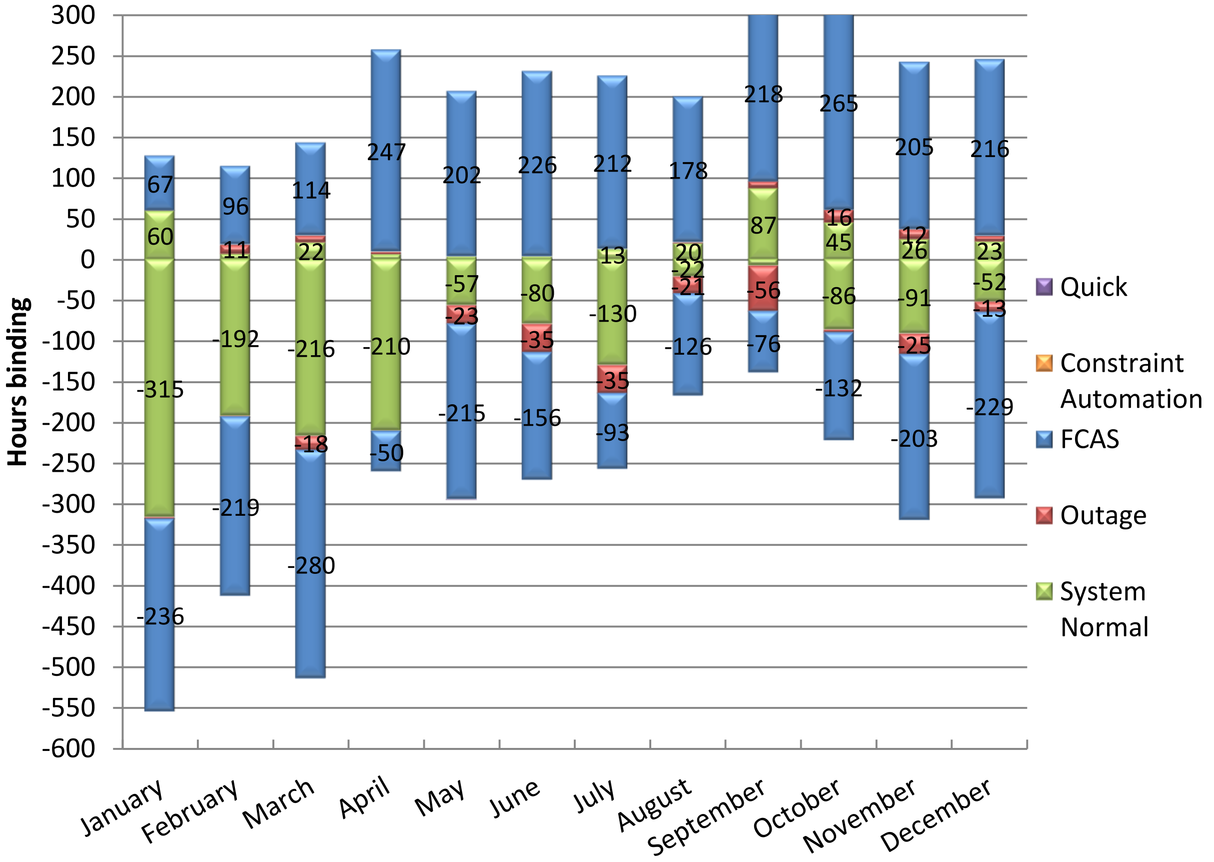

Figure 12: Categorized binding intervals per month for T-V-MNSP1

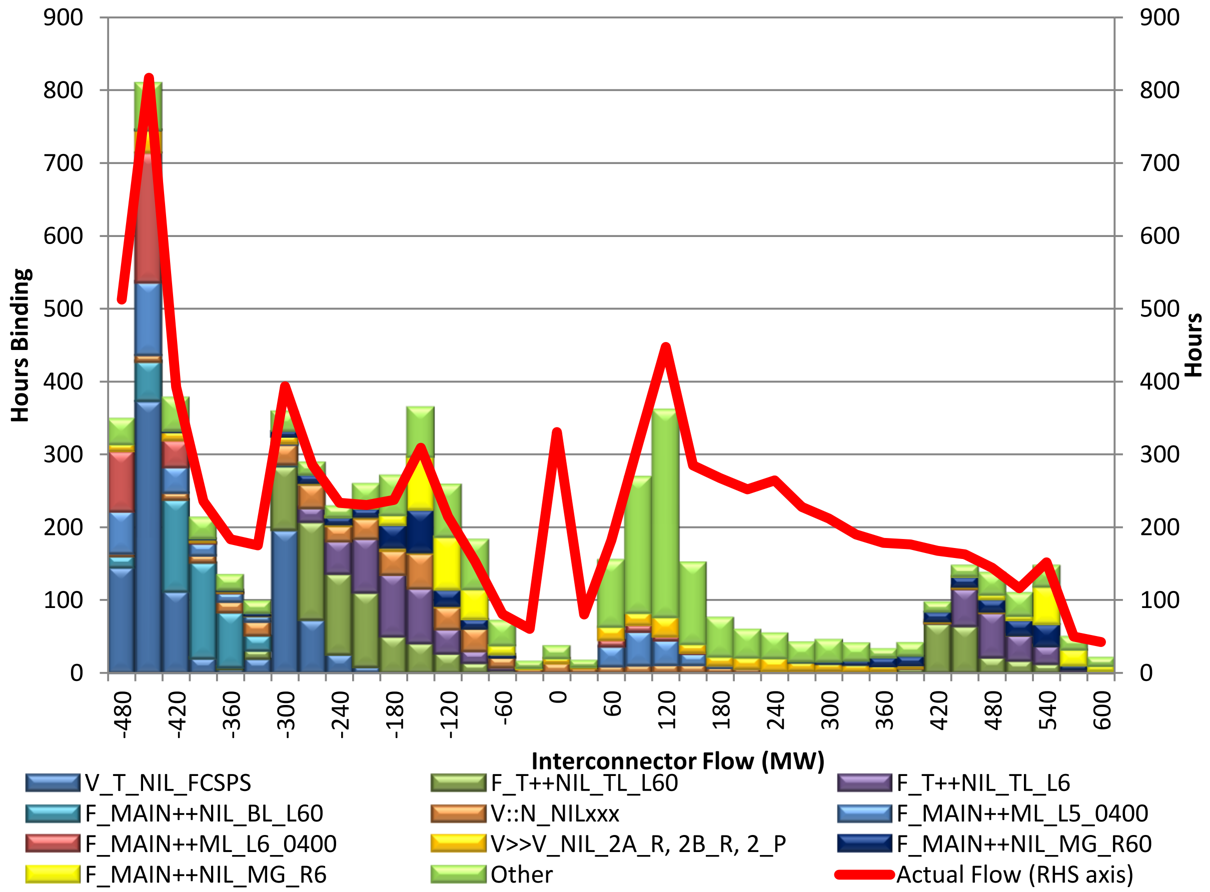

Figure 13: Binding constraint equation distribution for Basslink

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
F_T++NIL_TL_L60	771.0 (304.7)	*Tasmania lower 60 second FCAS requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_T++NIL_TL_L6	529.3 (54.0)	*Tasmania lower 6 second FCAS requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_MAIN++NIL_MG_R6	301.1 (130.8)	*Mainland raise 6 second FCAS requirement for a mainland generation event, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R60	297.2 (174.8)	*Mainland raise 60 second FCAS 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	280.9 (460.3)	*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
F_MAIN++NIL_MG_R5	165.6 (194.5)	*Mainland raise 5 minute FCAS requirement for a mainland generation event, Basslink able transfer FCAS*
F_T++NIL_TL_L5	164.6 (193.3)	*Tasmania lower 5 minute FCAS requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
TVBL_ROC	19.8 (11.8)	*Out = Nil, rate of change (Tasmania to Victoria) limit (200 MW / 5 minute) for Basslink*
V>>V-HWLY_1	11.1 (0)	*Out = Hazelwood to Loy Yang No.1 line, avoid overloading Hazelwood to Loy Yang No.2 or No.3 line on trip of any of the remaining Hazelwood o Loy Yang line*
F_T++LREG_0050	9.9 (11.5)	*Tasmania lower regulation FCAS requirement greater than 50 MW, Basslink able transfer FCAS*

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
V_T_NIL_FCSPS	972.8 (3136.3)	*Basslink limit from Victoria to Tasmania for load enabled for the Basslink frequency control special protection scheme (FCSPS)* See Table 3 for comments.
V::N_NILVxxx & V::N_NILQxxx	423.5 (135.2)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 3 for comments.
F_MAIN++NIL_BL_L60	423.3 (511.9)	*Mainland lower 60 second FCAS requirement for loss of Basslink, Basslink flow into Tasmania, Basslink able transfer FCAS*
F_MAIN++ML_L5_0400	363.1 (640.3)	*Mainland lower 5 minute FCAS requirement for a mainland load event, Basslink able transfer FCAS*
F_MAIN++ML_L6_0400	320.8 (45.8)	*Mainland lower 6 second FCAS requirement for a mainland load event, Basslink able transfer FCAS*
F_T++NIL_MG_R5	222.5 (41.5)	*Tasmania raise 5 minute FCAS requirement for a Tasmania generation event, Basslink able to transfer FCAS*
F_MAIN++APHY_L5	141.4 (111.7)	*Out = Alcoa Portland to Heywood line, lower 5 minute FCAS requirement for the loss of the remaining line, Basslink able to transfer FCAS* See Table 4 for comments
F_T++NIL_MG_R6	106.4 (40.7)	*Tasmania lower 60 second FCAS requirement for a Tasmania generation event (loss of the largest inertia), Basslink able to transfer FCAS*
F_QNV++HYML_L60	97.3	*Out = one Heywood to Moorabool or one Moorabool to Sydenham line*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
	(51.2)	*Queensland, NSW and Victoria lower 60 second FCAS requirement, Basslink able to transfer FCAS* The Heywood to Moorabool lines were out for 27.3 days in 2010 (compared to 17 days in 2009), see Table 19.
V::N_HWSMxxx	85.5 (31.6)	*Out = Hazelwood to South Morang line, avoid transient instability for fault and trip of a Hazelwood to South Morang 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.

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.

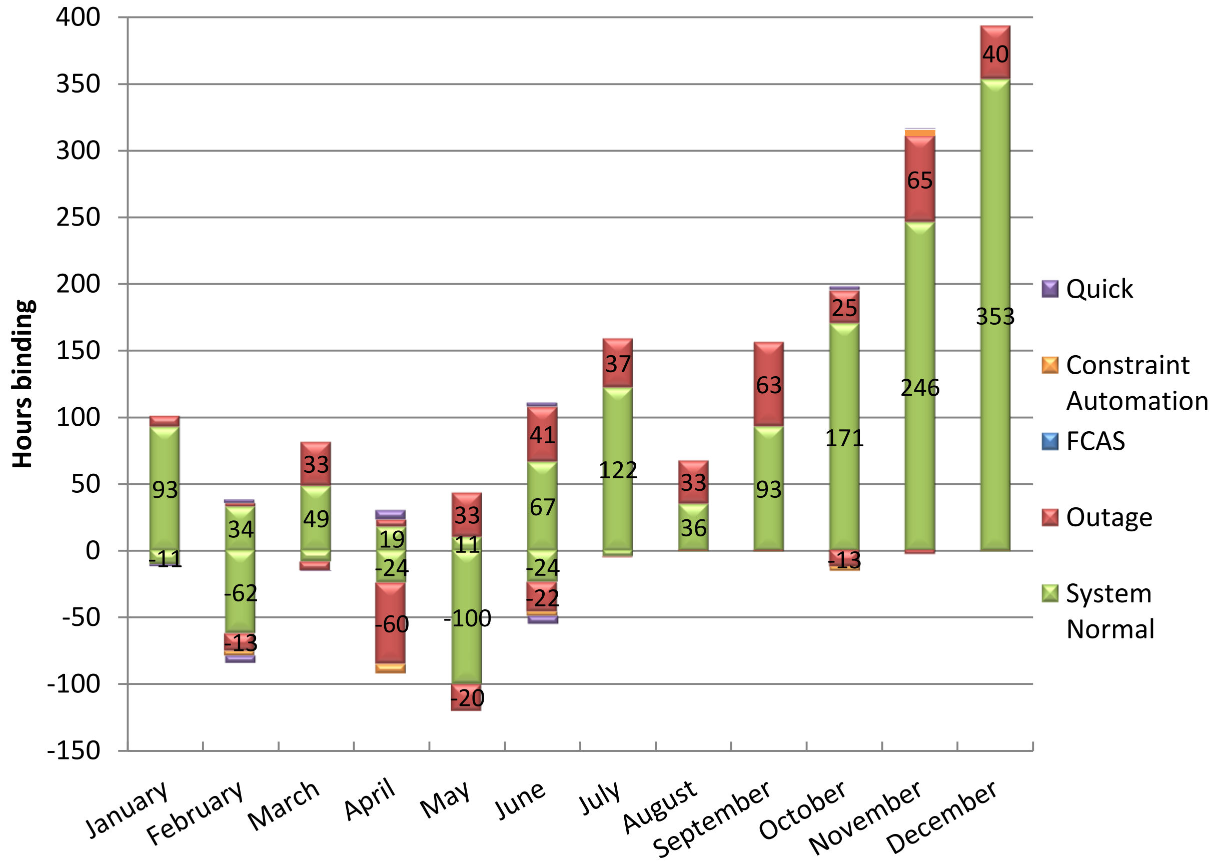

Figure 14: Categorized binding intervals per month for VIC1-NSW1

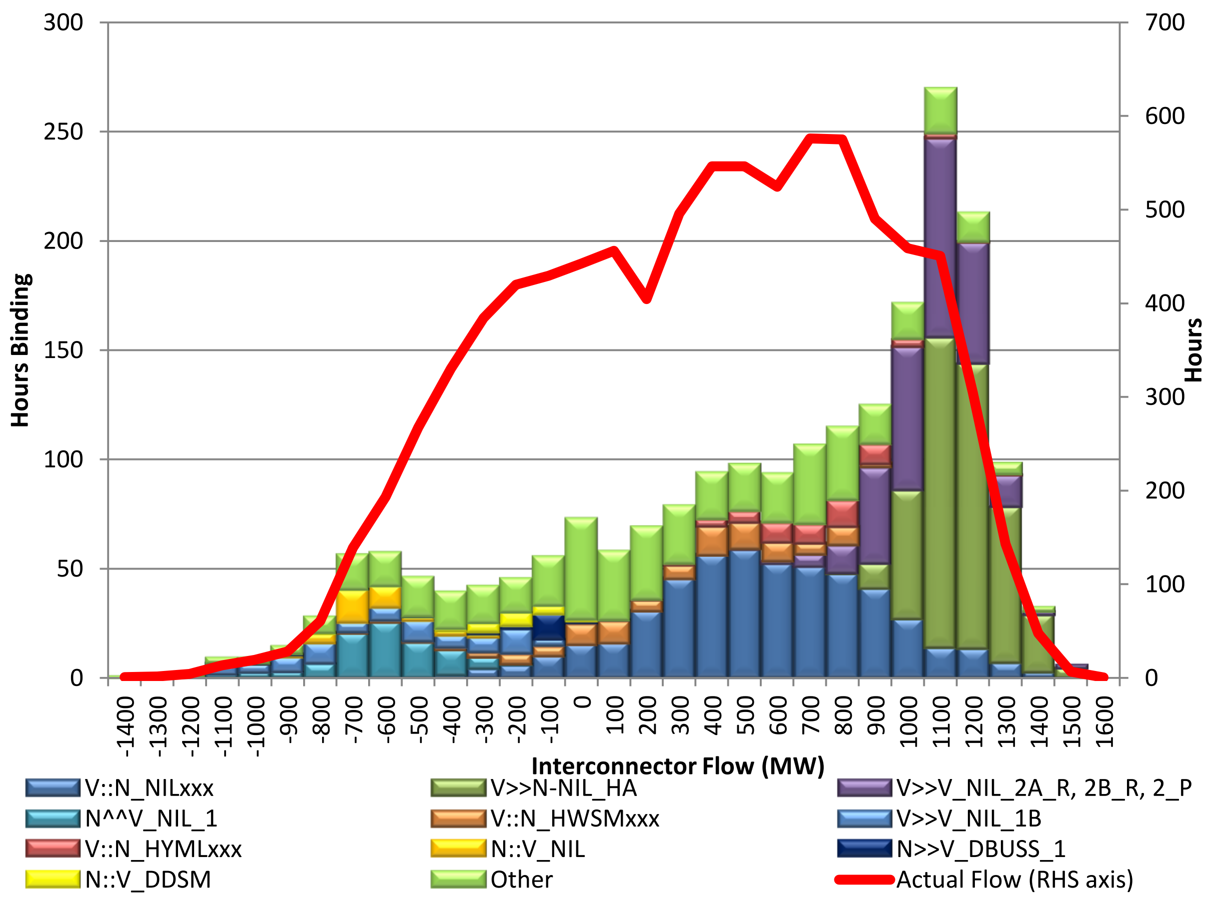

Figure 15: Binding constraint equation distribution for VIC1-NSW1

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
V::N_NILVxxx & V::N_NILQxxx	496.8 (204.9)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 3 for comments.
V>>N-NIL_HA	445.8 (34.2)	*Out = Nil, avoid overload on Murray to Upper Tumut (65) line on trip of Murray to Lower Tumut (66) line* See Table 3 for comments.
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	293.3 (480.4)	*Out = Nil, avoid overloading the South Morang 500/330 kV (F2) transformer for no contingencies, Yallourn W1 on the 500 or 220 kV* See Table 3 for comments.
V::N_HWSMxxx	93.2 (54.0)	*Out = Hazelwood to South Morang line, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 12 for comments.
V::N_HYMLxxx	53.0 (1.2)	*Out = Heywood to Moorabool line, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 10 for comments.
V::N_SMCSxxx	44.3 (412.0)	*Out = South Morang 330 kV series capacitor, avoid transient instability for fault and trip of a Hazelwood to South Morang 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.
N>>N-NIL__S	31.2 (28.3)	*Out= Nil, avoid overloading Mt Piper to Wallerawang (70) line on trip of Mt Piper to Wallerawang (71) line* See Table 6 for comments
V::N_SM330_2B	17.1 (0)	*Out = South Morang 330 kV No. 2 bus, avoid transient instability for fault and trip of a Hazelwood to South Morang line*
#VIC1-NSW1_E_E	15.5 (0)	*Quick constraint equation applied to VIC1-NSW1 at various levels* This quick constraint equation was invoked a number of times during 2010 to manage negative residues.
V>>V_TTS_B1_2	15.3 (0)	*Out = Thomastown No. 1 220 kV bus, avoid overloading Thomastown to South Morang No. 1 line on trip of South Morang 500/330 kV (F2) transformer*

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
N^^V_NIL_1	93.7 (62.7)	*Out = Nil, avoid voltage collapse for loss of the largest Victorian generating unit*
V>>V_NIL_1B	72.9 (12.4)	*Out = Nil, avoid overloading Dederang to Murray No.2 line for loss of the parallel No.1 line, 15 minute line ratings*
N::V_NIL	35.3 (2.3)	*Out = Nil, NSW to Snowy transient stability limit* This constraint equation was replaced in early 2011 by 5 new constraint equations (N::V_NIL_BWSW, N:V_NIL_BWRG, N:V_NIL_BYYS, N::V_NIL_MSDD, N::V_NIL_UTMS). These are not expected to bind in 2011.
N>>V_DBUSS_1	18.6	*Out = Dederang DBUSS - line control scheme, avoid overload of a Murray*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
	(0.1)	*to Dederang line for trip of the remaining Murray to Dederang line* DBUSS - line is a control scheme that splits Dederang 330 kV bus on trip of a Murray to Dederang line. This was implemented to allow higher NSW to Vic interconnector capability. For a number of outages in southern NSW and northern Victoria either the line or transformer control schemes are also taken out of service.
N::V_DDSM	14.8 (0)	*Out = one Dederang to South Morang line, NSW to Snowy transient limit* This constraint equation is based on N::V_NIL and it is expected N::V_DDSM will be replaced in 2011 with new constraint equations based on the 5 new NSW to Victoria transient stability constraint equations.
V>>V_NIL_4A	13.8 (10.3)	*Out = Nil, avoid overloading Dederang No.1 330/220 kV transformer for no contingencies, DBUSS - Transformer control scheme armed.* Similar to DBUSS - Line, the DBUSS – Transformer scheme splits the Dederang 330 kV bus on trip of a Dederang transformer
N>>N-DTKV_1S	12.3 (0)	*Out = Dapto to Kangaroo Valley (18) line, avoid overloading Marulan to Yass (4) line on trip of Marulan to Yass (5) line*
N>>V-NIL_O	12.2 (51.5)	*Out = Nil, avoid overloading Upper Tumut to Murray (65) line on trip of Lower Tumut to Wagga (051) line and subsequent tripping of 970,990, and 99M (out of Yass) 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. The Wagga 132 to Yass (990) 132 kV line has been out since May 2008 and will be unavailable until mid 2011. This increases the likelihood of this scheme operating so it is expected to continue to bind in the first half of 2011 (unless Wagga to Yass 132 kV network is radialised under high import into NSW from Victoria).
#VIC1-NSW1_I_E	11.2 (10.4)	*Quick constraint equation applied to VIC1-NSW1 at various levels* This quick constraint equation was invoked a number of times during 2010 to manage negative residues.
V>>V_TTS_B1_3B	10.3 (0)	*Out = Thomastown No. 1 220 kV bus, avoid overloading Richmond to Brunswick cable on trip of South Morang 500/330 kV (F2) transformer, Victorian radial mode*

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 was increased to 580 MW in January 2011.

Victoria to SA flow is most often restricted by the voltage collapse limit in south east SA. V-SA appears in many of the Victorian constraint equations and these can limit both directions of flow on this interconnector. Export from SA is also restricted by the thermal limits on the South East substation 275/132 kV transformers as well as the combined upper limit of 420 MW.

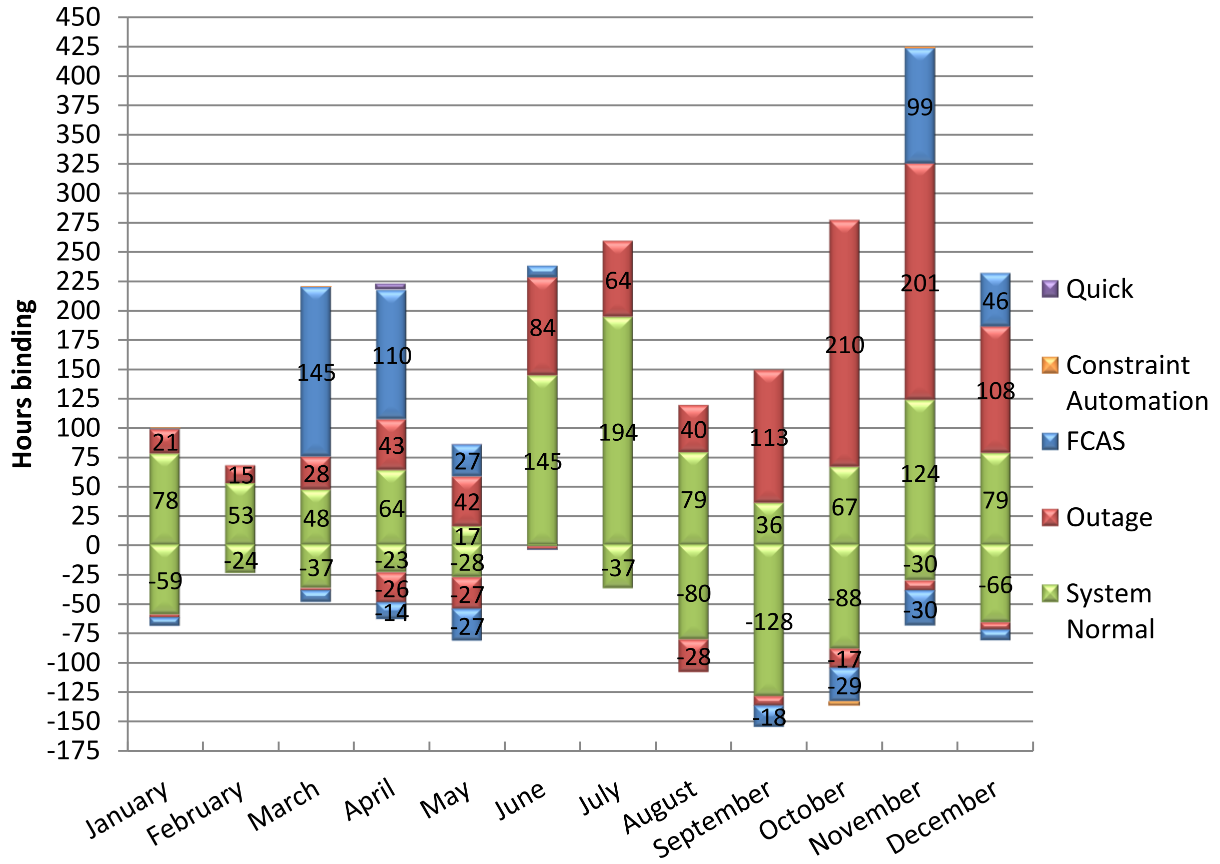

Figure 16: Categorized binding intervals per month for V-SA

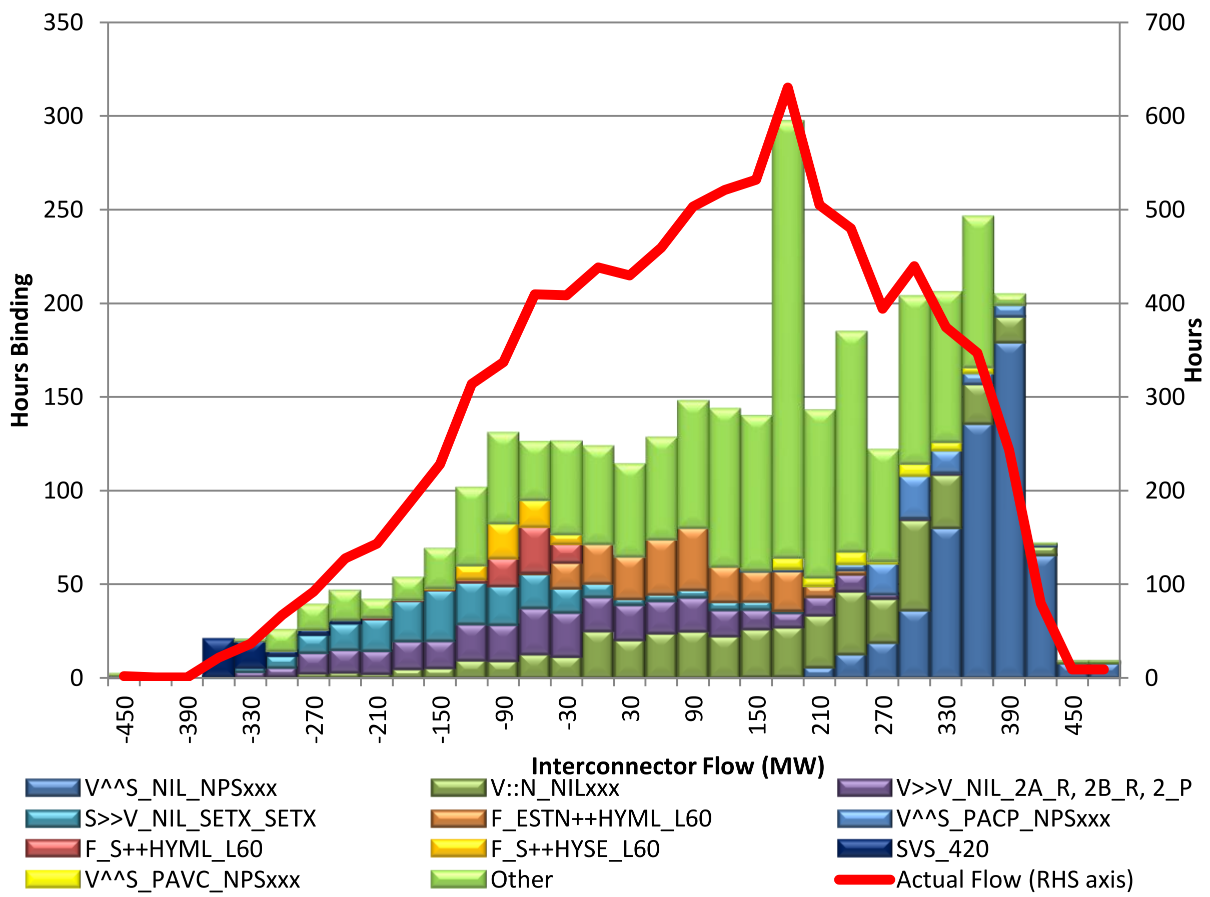

Figure 17: Binding constraint equation distribution for V-SA

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
V^^S_NIL_NPS_SE_OFF & V^^S_NIL_NPS_SE_ON & V^^S_TBCP_NPS_SE_OFF & V^^S_TBCP_NPS_SE_ON	542.0 (624.4)	*Out = Nil, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off, Tailem Bend capacitor bank on/off* See Table 3 for comments.
V::N_NILVxxx & V::N_NILQxxx	429.9 (190.1)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 3 for comments.
V^^S_PACP_NPS_SEOFF & V^^S_PACP_NPS_SEON	234.8 (0)	*Out = one Para capacitor, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off* See Table 3 for comments.
F_ESTN++HYML_L60	184.8 (55.3)	*Out = one Heywood to Moorabool or one Moorabool to Sydenham line Eastern lower 60 second FCAS requirement*
V^^S_PAVC_NPS_SEOFF & V^^S_PAVC_NPS_SEON	124.4 (0)	*Out = one Para SVC, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off* This constraint equation was created in 2010 and the capacitor bank was out for 24 days (see Table 19).
F_ESTN++HYML_L5	104.2 (40.8)	*Out = one Heywood to Moorabool or one Moorabool to Sydenham line Eastern lower 5 minute FCAS requirement*
V::N_HWSMxxx	89.1 (54.6)	*Out = Hazelwood to South Morang line, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See comment on Table 13
F_QNV++HYML_L60	71.2 (76.1)	*Out = one Heywood to Moorabool or one Moorabool to Sydenham line, Qld, NSW, Snowy and Vic lower 60 second FCAS requirement, Basslink able to transfer FCAS*
V>>S_HYML_2	67.1 (0)	*Out = Heywood to Moorabool to Aloca Portland line, avoid overloading Heywood 500/275 kV transformer for trip of Northern Power Station unit 2*
V>>S_HYML_1	66.7 (0)	*Out = Heywood to Moorabool to Aloca Portland line, avoid overloading Heywood 500/275 kV transformer for trip of Northern Power Station unit 1*

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	287.1 (493.0)	*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.
S>>V_NIL_SETX_SETX	203.6 (67.7)	*Out = Nil, avoid overloading a South East 275/132 kV transformer on trip of the other South East 275/132 kV transformer* See Table 3 for comments.
F_S++HYML_L60	52.0 (29.7)	*Out = one Heywood to Moorabool or one Moorabool to Sydenham line, SA lower 60 second FCAS requirement*
F_S++HYSE_L60	45.4 (57.2)	*Out = one Heywood to South East or one Heywood 500/275 kV (M1 or M2) transformer, SA lower 60 second FCAS requirement*
SVS_420	41.8 (5.0)	*SA to Victoria on both Vic-SA and Murraylink upper transfer limit of 420 MW* Prior to 2011 this constraint equation represented the oscillatory stability

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
		limit on combined Vic-SA and Murraylink transfer from SA to Victoria. In early 2011 AEMO completed oscillatory stability studies and this limit was raised to 580 MW (constraint equation S:V_580). It is possible that SVS_420 may continue to be used in outage cases. However, it is not expected to bind with the same frequency in 2011.
N::V_NIL	35.8 (2.3)	*Out = Nil, NSW to Snowy transient stability limit* See Table 14 for comments. The new transient stability limits no longer include a V-SA term on the LHS.
S>>V_NIL_PWSETX_SETX	22.9 (0)	*Out = Nil, avoid overloading the a South East 275/132 kV transformer on trip of the remaining South East 275/132 kV transformer and Penola West to South East line* This constraint equation was introduced in April 2010, after consultation with ElectraNet SA, to model the impact of the South East transformer control scheme (which trips the Penola West to South East line on trip of a South East transformer). In December 2010, on advice from ElectraNet SA, the constraint equation was removed.
F_S++HYML_L6	19.0 (13.8)	*Out = one Heywood to Moorabool or one Moorabool to Sydenham line, SA lower 6 second FCAS requirement*
N::V_DDSM	18.8 (0)	*Out = Dederang to South Morang line, NSW to Snowy transient stability limit* See Table 14 for comments.
S>SECB6161_SETX_SGBL	18.0 (0)	*Out = South East CB 6161, avoid overloading Snuggery to Blanche line for trip of South East 275/132 kV #2 transformer*

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 network from Robertstown to Monash and Robertstown to Waterloo.

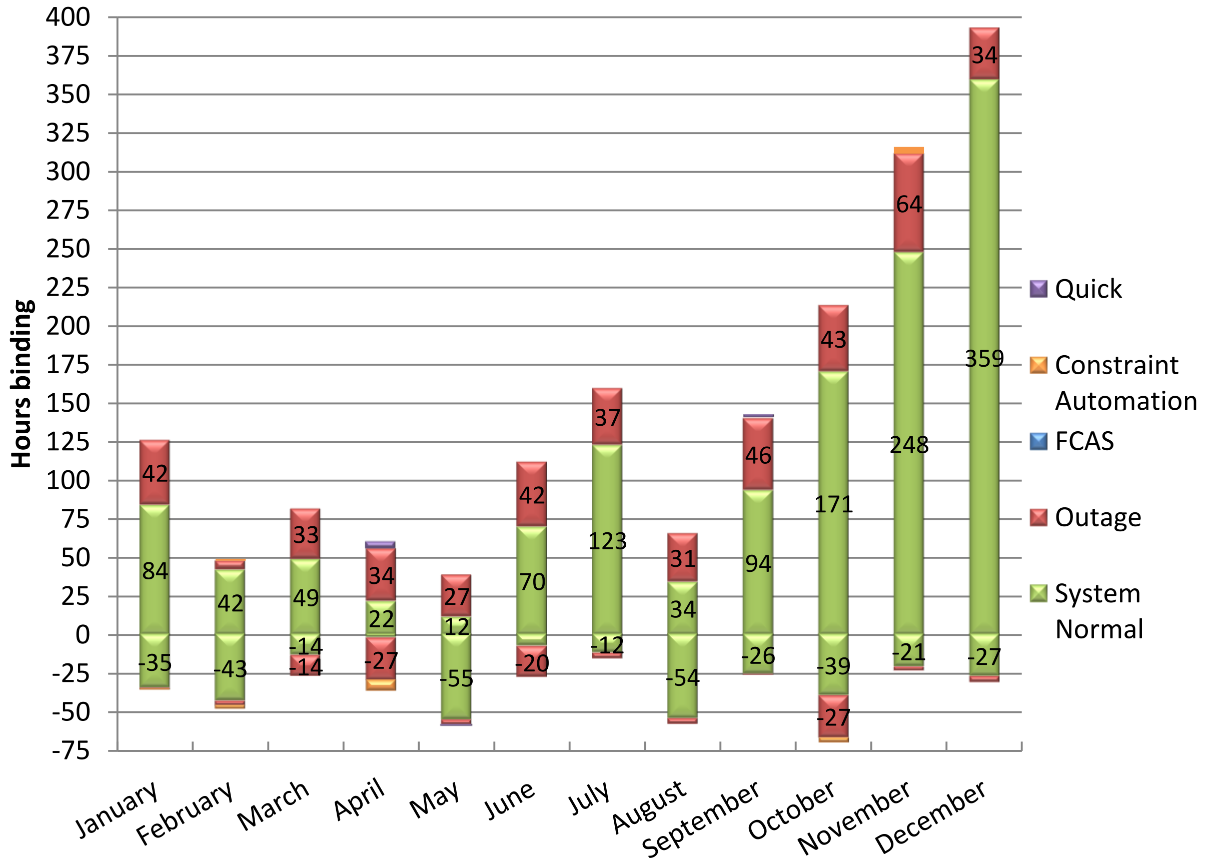

Figure 18: Categorized binding intervals per month for V-S-MNSP1

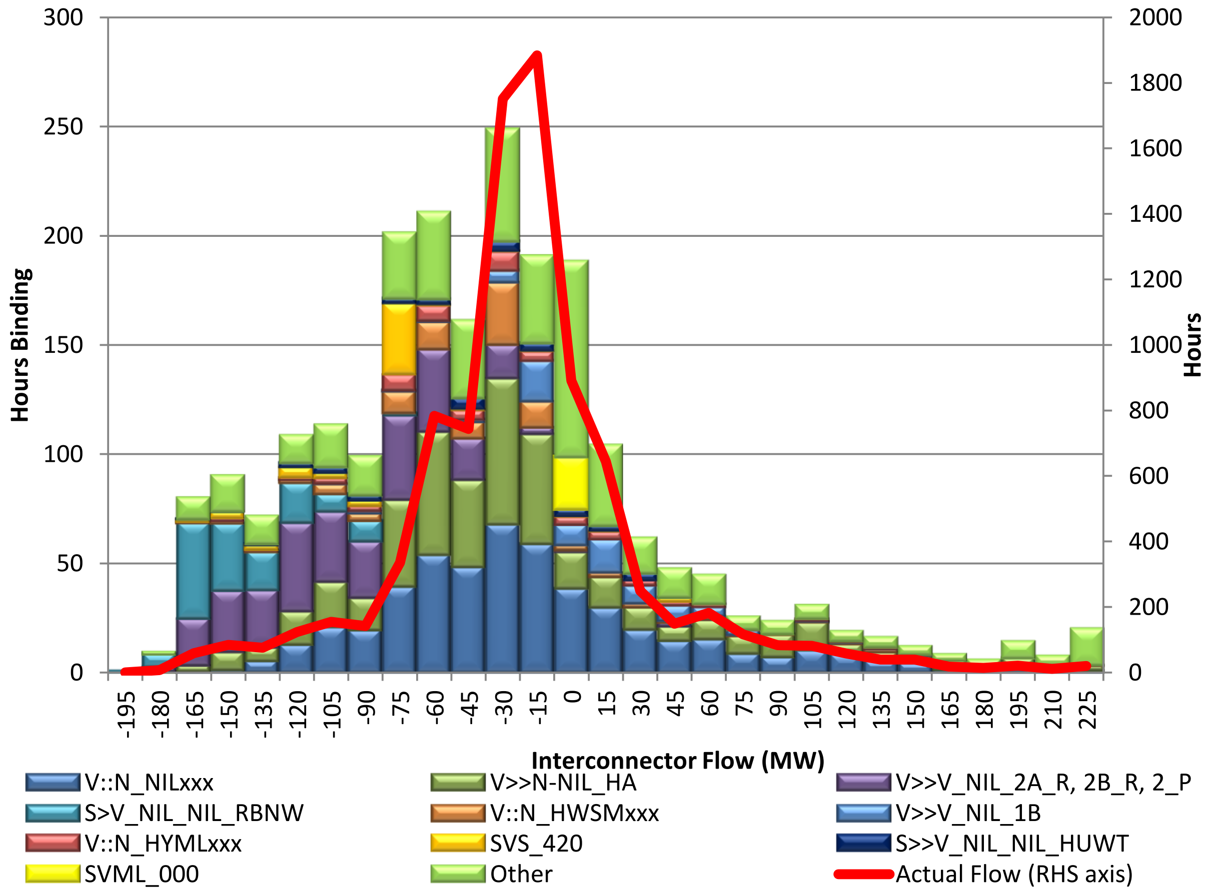

Figure 19: Binding constraint equation distribution for Murraylink

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
V::N_NILVxxx & **V::N_NILQxxx**	495.5 (204.1)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 3 for comments.
V>>N-NIL_HA	438.2 (34.4)	*Out = Nil, avoid overload on Murray to Upper Tumut (65) line on trip of Murray to Lower Tumut (66) line* See Table 3 for comments.
V>>V_NIL_2A_R & **V>>V_NIL_2B_R &** **V>>V_NIL_2_P**	294.5 (488.2)	*Out = Nil, avoid overloading the South Morang 500/330 kV (F2) transformer for no contingencies, Yallourn W1 on the 500 or 220 kV* See Table 3 for comments.
V::N_HWSMxxx	92.9 (54.6)	*Out = Hazelwood to South Morang line, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 13 for comments
V::N_HYMLxxx	52.6 (1.2)	*Out = Heywood to Moorabool line, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 10 for comments.
VSML_000	46.2 (31.3)	*Victoria to SA on Murraylink upper transfer limit of 0 MW* Murraylink was out for 3.2 days in 2010 compared to 3.6 days in 2009 (see Table 19).
V::N_SMCSxxx	44.3 (407.4)	*Out = South Morang 330 kV series capacitor, avoid transient instability for fault and trip of a Hazelwood to South Morang line* See Table 13 for comments.
V>SMLBAHO1	32.3 (11.8)	*Out = Ballarat to Horsham, or Bendigo to Kerang line, avoid overloading or voltage collapse on Buronga to Balranald to Darlington Point (X5) line for trip of Bendigo to Kerang or Ballarat to Horsham line* The Bendigo to Kerang lines were out for 8.6 days in 2010 (compared to 0.6 days in 2009), see Table 19. There were no outages of the Ballarat to Horsham lines in 2010 compared to 4.1 days in 2009.
V^SML_NSWRB_2	23.4 (56.3)	*Out = NSW Murraylink runback scheme, avoid voltage collapse for trip of Darlington Point to Buronga (X5) line* See Table 6 for comments
V>SMLBAHO4	15.8 (0)	*Out = Ballarat to Horsham or Bendigo to Kerang line, avoid overloading Buronga to Redcliffs (0X1) line for trip of Bendigo to Kerang, or Ballarat to Horsham line*

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

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
S>V_NIL_NIL_RBNW	136.9 (200.3)	*Out = Nil, avoid overloading North West Bend to Robertstown line for no contingencies* This constraint equation normally sets the upper limit on Murraylink and is expected to bind with similar frequency in 2011.
V>>V_NIL_1B	76.6 (16.2)	*Out = Nil, avoid overloading Dederang to Murray No.2 line for loss of the parallel No.1 line, 15 minute line ratings*
SVS_420	49.8	*SA to Victoria on both Vic-SA and Murraylink interconnectors upper*

EQUATION ID (SYSTEM NORMAL IN BOLD)	HOURS (2009)	*DESCRIPTION* / NOTES
	(35.3)	*transfer limit of 420 MW* See Table 16 for comments.
S>>V_NIL_NIL_HUWT	35.4 (0)	*Out = Nil, avoid overloading Hummocks to Waterloo line for no contingencies* This constraint equation was introduced in mid 2010. It replaced S>V_NIL_NIL_HUWT. Murraylink was moved to the LHS as a part of compliance with the new CFG (which became active on 1st June 2010) and this caused the change in the ID.
SVML_000	23.8 (45.4)	*SA to Victoria on Murraylink upper transfer limit of 0 MW* Murraylink was out for 3.2 days in 2010 compared to 3.6 days in 2009 (see Table 19).
S>>V_NIL_WTTP_WEMW4	21.9 (0)	*Out = Nil, avoid overloading Waterloo East to Morgan Whyalla pump 4 line on trip of Waterloo to Templers line* This constraint equation was introduced in late 2010 following the commissioning of the Waterloo wind farm.
N>>V_DBUSS_1	19.0 (0.2)	*Out = Dederang DBUSS-line control scheme, avoid overload of a Murray to Dederang line for trip of the remaining Murray to Dederang line* See Table 14 for comments
S>VML_NWCB6225_TX1	13.6 (0)	*Out = North West Bend CB 6225, avoid overloading North West Bend transformer #1 on trip North West Bend to Morgan Whyalla pump #1 line*
S>>V_NIL_NIL_MNWT	7.4 (0)	*Out = Nil, avoid overloading Mintaro to Waterloo line for no contingencies*
V>>V_TTS_B1_3B	5.9 (0)	*Out = Thomastown No. 1 220 kV bus, South Morang 220 kV busses tied, avoid overloading Richmond to Brunswick cable on trip of South Morang 500/330 kV (F2) transformer, Victorian radial mode*

10 Major network outages

The following table shows the duration of the network outages in 2010 that required any of the binding constraint equations included in the tables in sections 7 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	243.0 (142.6)	*One Directlink cable*
N-X_MBTE_2	121.1 (11.4)	*Two Directlink cables*
N-EWMB_8505	86.0 (13.1)	*One Ballina to Lennox Head to Ewingsdale to Mullumbimby 66 kV line (8504, 8505 or 8508) or Mullumbimby 132/66 kV transformer*
F-V-APHY_ONE	71.3 (33.6)	*Alcoa Portland to Heywood 500 kV line* The outages are mainly due to the rebuilding both the Alcoa Portland to Heywood lines
S-PA_CAP	49.1 (0)	*One Para Capacitor*
Q-BCGL_812	30.1 (19.3)	*Bouldercombe to Gladstone (812) 275 kV line*

CONSTRAINT SET ID	DAYS	*OUTAGE* / NOTES
F-V-HYML & V-HYML	27.3 (17.0)	*Heywood to Moorabool 500 kV line* These outages are due to installation of optic fibre earth wire and the establishment of the Mortlake terminal station
N-KKLS_967	25.4 (14.1)	*Koolkhan to Lismore (967) 132 kV line* These outages are due to pole replacement work on the 967 line
S-PA_VC_1	24.7 (6.8)	*One Para SVC*
Q-GBMU_835_836	20.1 (0)	*One Greenbank to Mudgeeraba (835 or 836) 275 kV line*
Q-BRTR_8814_8815	14.5 (3.1)	*One Braemar to Tarong (8814 or 8815) 275 kV line*
N-X_MBTE_3	14.2 (5.7)	*All three Directlink cables*
F-V-HY_TX & V-HYTX	11.9 (10.7)	*One Heywood 500/275 kV (M1 or M2) transformer*
N-DTKV_18	11.3 (1.0)	*Dapto to Kangaroo Valley (18) 330 kV line*
V-SMSC	8.7 (136.5)	*One or both South Morang 330 kV series capacitors*
T-FASH_xxx	8.6 (2.8)	*One Farrell to Sheffield 220 kV line* Farrell to Sheffield outages can have a number of bus configurations at Farrell and the times for each of these have been combined.
V-BEKG	8.6 (0.6)	*Bendigo to Kerang 220 kV line*
F-I-HYSE & I-HYSE	7.4 (0.8)	*One Heywood to South East 275 kV line*
V-HWSM	7.3 (5.4)	*Hazelwood to South Morang 500 kV line*
V-DDGN	7.2 (2.3)	*One Dederang to Glenrowan 220 kV line*
Q-H13RS_SVC	6.3 (12.3)	*Ross SVC*
V-HWLY_1	5.8 (1.9)	*Hazelwood to Loy Yang No.1 500 kV line*
Q-SMRS	5.8 (0)	*One Strathmore to Ross (879 or 880) 275 kV line* There are 2 configuration modes this outage can be run in (with the parallel 132 kV lines in service or out). The times for each have been combined.
V-DDSM	4.3 (3.6)	*One Dederang to South Morang 330 kV line*
V-TTS-1B_R & V-TTS-1B_P	4.1 (0)	*Thomastown No. 1 220 kV bus* The times for both the radial and parallel mode constraint sets have been combined. These outages are due to rebuilding of the Thomastown substation. This work is expected to be completed in 2011.
F-T-N-ARTW_85 & N-ARTW_85	4.0 (2.4)	*Armidale to Tamworth (85 or 86) 330 kV line*
S-X_BLMK+DVBL	3.8 (0)	*Belalie to Mokota and Davenport to Belalie 275 kV lines*
N-CHLS_89	3.4 (3.9)	*Coffs Harbour to Lismore (89) 330 kV line*

CONSTRAINT SET ID	DAYS	*OUTAGE* / NOTES
I-ML_ZERO	3.2 (3.6)	*Limit Murraylink to zero in either direction*
S-SE_CB6160-CB6162	3.1 (2.4)	*South East 132 kV circuit breaker CB6160 or CB6162*
V-HWCB4	2.7 (0.3)	*Hazelwood to Cranbourne No.4 500 kV line*
N-AR_VC1	2.5 (5.5)	*Armidale SVC*
S-BGPA	2.4 (0)	*Bungama to Para 275 kV line*
V-HWRO3	1.8 (0)	*Hazelwood to Rowville No.3 500 kV line*
I-MSUT	1.6 (16.3)	*Murray to Upper Tumut (65) 330 kV line*
N-X_ARKK_CH_CB892A	1.5 (1.3)	*Armidale to Koolkhan (966) 132 kV line and Coffs Harbour CB 892A*
S-SECB6161	1.4 (0)	*South East 132 kV circuit breaker CB6161*
S-CNHL_HAL	1.3 (0)	*Canowie to Hallett 275 kV line*
N-X_89_LSTX_SVC	1.1 (0.0)	*Coffs Harbour to Lismore (89) 330 kV line and Lismore 330/132 kV transformers*
S-NW_CB6225	0.9 (0)	*North West Bend circuit breaker CB6225*

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 the constraint equations in real time automatically. However, 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.

AEMO intends to release a discussion paper on the future of the constraint automation in early 2011.

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 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 Predispatch
- 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 high risk that SPD IDs could be missed. This feature will be delivered in mid 2011.

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[8].

No issues were identified for the constraint automation in 2010.

11.1.4 Usage

Figure 20 below shows the usage of the constraint automation in 2008, 2009 and 2010. 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 a 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 much higher than reported in Figure 20.
  - 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 several 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).

[8] http://www.aemo.com.au/electricityops/0200-0006.html

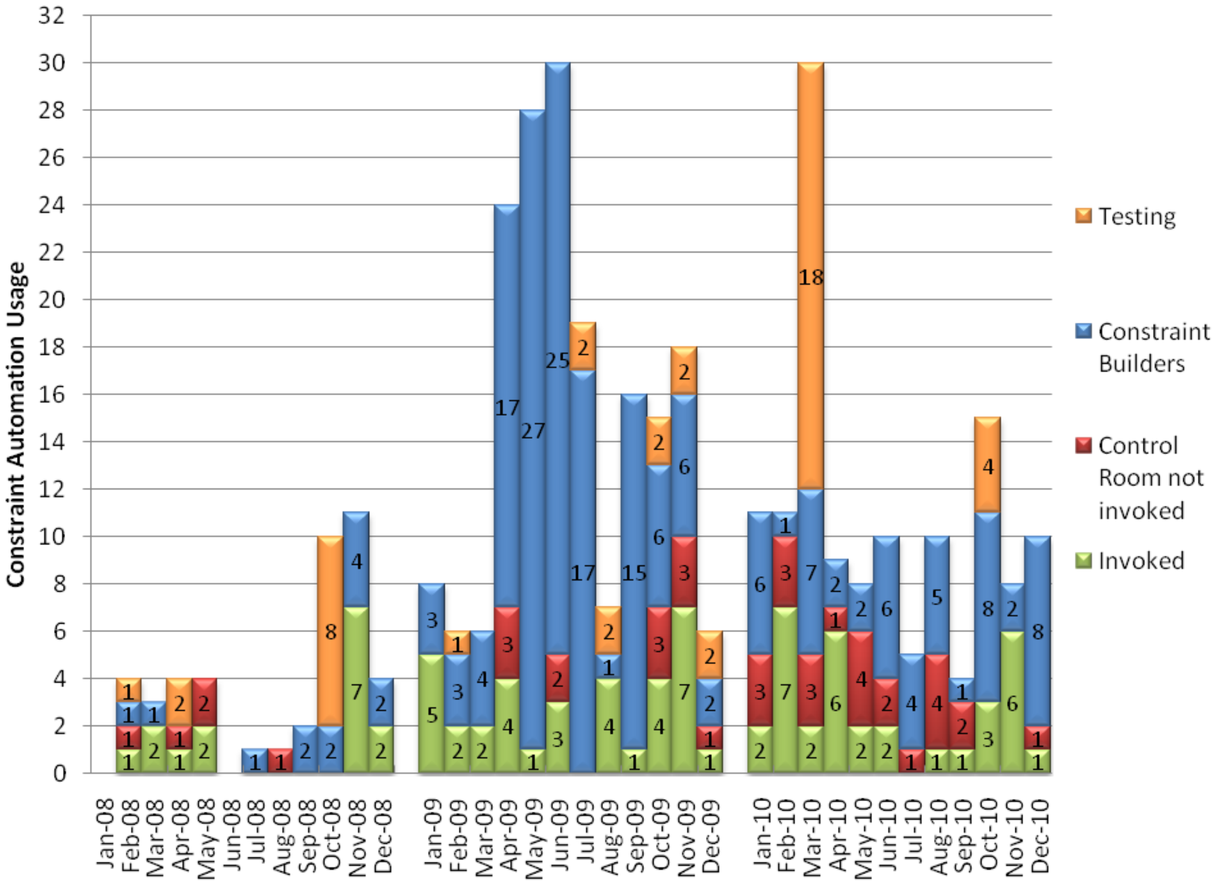

Figure 20: Constraint automation usage in 2008, 2009 and 2010

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 conducted a consultation for the first CIR in 2010. From the consultation the summated LHS in the constraint equation results was added in late 2010. A number of other items will be added in 2011:

- Dispatch, Predispatch and PASA interconnector and constraint equation results added to the MMS web portal
- Extra fields added to the published network outage schedule (NOS).

A further consultation on the CIR will be held in early 2011.

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

This report is included in the CIR.

12 Appendix 1: Market impact of constraint equations 2009

Table 20: Top 20 market impact constraint equations in 2009

EQUATION ID (SYSTEM NORMAL BOLD)	Σ MARGINAL VALUES	HOURS	*DESCRIPTION* / NOTES
T_TAMARCCGT_GCS	$2,855,945	293.33	*Limit output of Tamar Valley Power Station based on load available for shedding by Tamar Valley 220 kV GCS* See Table 3 for comments
F_T+NIL_BL_R6 & F_T+NIL_BL_R6_1 & F_T++NIL_BL_R6_x	$2,508,345	5,376.3	*Tasmania raise 6 second FCAS requirement for loss of Basslink, FCSPS available* See Table 4 for comments
V^^S_NIL_NPS_xxx & V^^S_TBCP_NPS_xxx	$2,464,858	668.5	*Out = Nil, Victoria to SA long term voltage stability limit for loss of one Northern unit, South East capacitor bank on / off, Tailem Bend capacitor bank on/off* See Table 3 for comments
V_T_NIL_FCSPS	$2,199,934	3966.42	*Basslink limit from Victoria to Tasmania for load enabled for the Basslink FCSPS* See Table 3 for comments
F_T+NIL_BL_R60 & F_T+NIL_BL_R60_1 & F_T++NIL_BL_R60_x	$1,823,770	4965.00	*Tasmania raise 60 second FCAS requirement for loss of Basslink, FCSPS available* See Table 4 for comments
V^SML_NSWRB_2	$1,815,493	60.7	*Out = NSW Murraylink runback scheme, avoid voltage collapse for trip of Darlington Point to Buronga (X5) line* See Table 6 for comments
F_T+NIL_BL_R5	$1,802,172	4530.08	*Tasmania raise 5 minute FCAS requirement for loss of Basslink, FCSPS available* See Table 4 for comments
N>>N-NIL__S	$1,198,350	36.6	*Out = Nil, avoid overloading Mt Piper to Wallerawang (70) on trip of Mt Piper to Wallerawang (71) line* See Table 6 for comments
Q>CLBCN_RUNBACK_OFF	$1,060,075	86.42	*Out = Ergon Runback Scheme, avoid overloading one Columboola to Chinchilla 132 kV line*
V>V_NIL_4	$926,129	72.42	*Out = Nil, avoid overloading Hazelwood No.1 500/220 kV transformer, Hazelwood in radial mode*
S>NIL_NIL_MNWT	$869,406	15.2	*Out = Nil, avoid overloading Mintaro to Waterloo line for no contingencies*
V>>S_NIL_KHTB2_KHTB1	$753,738	17.67	*Out = Nil, avoid overloading Keith to Tailem Bend #1 line for trip of Keith to Tailem Bend #2 line*
V>SML_NIL_8	$686,994	27.83	*Out = Nil, avoid overloading Ballarat to Bendigo line for trip of Bendigo to Fosterville to Shepparton line*
S>V_NIL_NIL_RBNW	$567,073	194.00	*Out = Nil, avoid overloading North West Bend to Robertstown line for no contingencies* See Table 18 for comments
S>NIL_DVPF_WYCL	$452,425	36.83	*Out = Nil, avoid overloading Whyalla Terminal to Cultana line on trip Playford to Davenport line*

EQUATION ID (SYSTEM NORMAL BOLD)	Σ MARGINAL VALUES	HOURS	*DESCRIPTION* / NOTES
N>>N-MNMP_ONE_1	$437,668	76.42	*Out = Marulan to Mt. Piper (35 or 36) line, avoid overloading Mt Piper to Wallerawang (70) line on trip of Mt Piper to Wallerawang (71) line*
V>>SML_NIL_1	$422,018	9.42	*Out = Nil, avoid overloading Ballarat to Moorabool No.1 line for trip of Ballarat to Moorabool No.2 line*
V::V_1900	$411,737	5.17	*Out = Nil, NSW to Victoria oscillatory stability limit of 1900 MW*
S_PLN_ISL1	$408,637	3.6	*Out = Whyalla to Yadnarie line, Port Lincoln units 1 and 2 islanded*
F_T+LREG_0050	$403,527	503.75	*Tasmania lower regulation FCAS requirement greater than 50 MW, Basslink unable to transfer FCAS*