NEM CONSTRAINT REPORT 2013

FOR THE NATIONAL ELECTRICITY MARKET

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide information about constraint equation performance and related issues, as at the date of publication.

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EXECUTIVE SUMMARY

AEMO uses constraint equations to model power system congestion in the National Electricity Market dispatch engine (NEMDE) and projected assessment of system adequacy (PASA). Constraint equations can have an impact on pricing and dispatch in the electricity market. AEMO publishes this report annually to provide market participants with information about the changing congestion patterns over the previous five years.

This report details constraint equation performance and transmission congestion related issues for calendar year 2013. It includes:

- The drivers for constraint equation changes in 2013.
- Analysis of binding constraint equations.
- Market impact of constraint equations.
- Constraint equations that set interconnector limits.
- Duration of outages.
- Information on other constraint-related issues.

Key Findings

1. The 2013 year saw the largest number of transmission and generator changes since 2009. This led to the largest number of constraint equation changes since 2010 and the first increase since 2009 (see chapter 2). The market impact due to constraint equations was the second highest since the data became available in 2009. This increase was mainly due to the market impact of system normal constraint equations in Tasmania (see chapter 4).

Year	Constraint changes	Market impact
2009	8594	$39 million
2010	6250	$28.3 million
2011	4776	$21.3 million
2012	4130	$30.3 million
2013	5817	$37.5 million

2. In 2013 the binding flow hours on the Queensland to New South Wales interconnector reversed direction to now bind from New South Wales to Queensland. Before 2013 the largest number of binding hours was from Queensland to New South Wales for flows greater than 1000 MW. In 2013 the binding flow hours were from New South Wales to Queensland for flows greater than 100 MW (see section 5.2).

Report streamlined

This 2013 report has a revised format. AEMO reviewed the contents of the report in early 2014 to streamline it and reduce duplication with the monthly constraint report. The key changes were:

- Removed the tabulated results in the second half of the report and included these in a separate spread sheet. [1]
- Removed the “Violating Constraint Equation” chapter. This information is available in AEMO’s monthly constraint report.[2]
- Removed the monthly constraint equation changes graph. This graph is available in AEMO’s monthly constraint reports.
- Removed categorised binding interval graphs from Chapter 7. The existing histograms were retained as they provide better information.

AEMO sourced the data for this report from the Electricity Market Management System (EMMS) to generate the tables and graphs and the network augmentation information from AEMO’s monthly constraint report.

[1] AEMO. *NEM Constraint Report 2013 Supplementary Data*. Available at: http://www.aemo.com.au/Electricity/Market-Operations/Dispatch/Annual-NEM-Constraint-Report

[2] AEMO. *Monthly Constraint Report*. Available at: http://www.aemo.com.au/Electricity/Market-Operations/Dispatch/Monthly-Constraint-Report.

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TABLES

FIGURES

1. CURRENT CONSTRAINT STATISTICS

This chapter details the total number of constraint sets, equations, and functions available in AEMO's electricity market management system (MMS) as of 31 December 2013. There were:

- 3,410 constraint sets. Down from 3,597 in 2012.
- 9,935 constraint equations. Up (by 190) from 9,745 in 2012.
- 366 constraint functions. Down from 401 in 2012.

Excluded from these totals are any constraint sets, equations, or functions that were archived prior to December 2013 and any that were created by the outage ramping process.[3] Outage ramping constraint sets and equations are generated for single use by AEMO's control room staff, so these are excluded from the results above.

The following two figures exclude outage ramping and constraint automation built constraint equations as both of which would swamp the results. Also excluded are any constraint equations that are not in a constraint set (and therefore cannot be active in NEMDE).

These figures show the breakup of constraint equation by region, frequency control ancillary services (FCAS), and other types (Figure 1-1), and by limit type (Figure 1-2).

Figure 1-1 — Constraint equations by region, FCAS, and other type

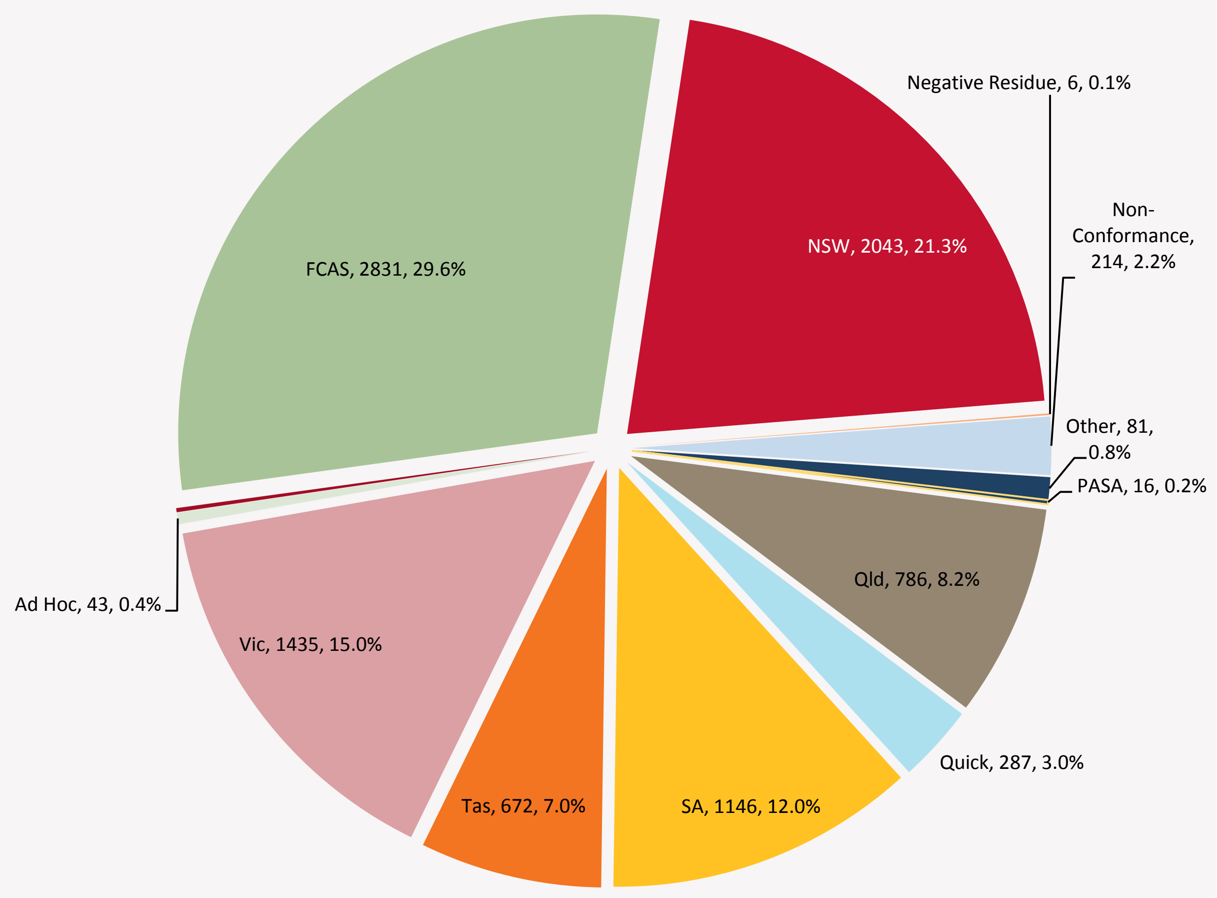


Figure 1-1 shows that most constraint equations are for FCAS, New South Wales, and then Victoria. Figure 1-2 below shows that the main types of constraint equations are for thermal overloads (32.0%) and FCAS (19.6%).

[3] Outage ramping constraint equations have IDs of the form #Rxxxxx_yyy_RAMP.

Quick constraint equations (in Figure 1-1) are produced by AEMO's control room staff for a selected number of left-hand-side (LHS) terms and a constant right-hand-side (RHS) value.

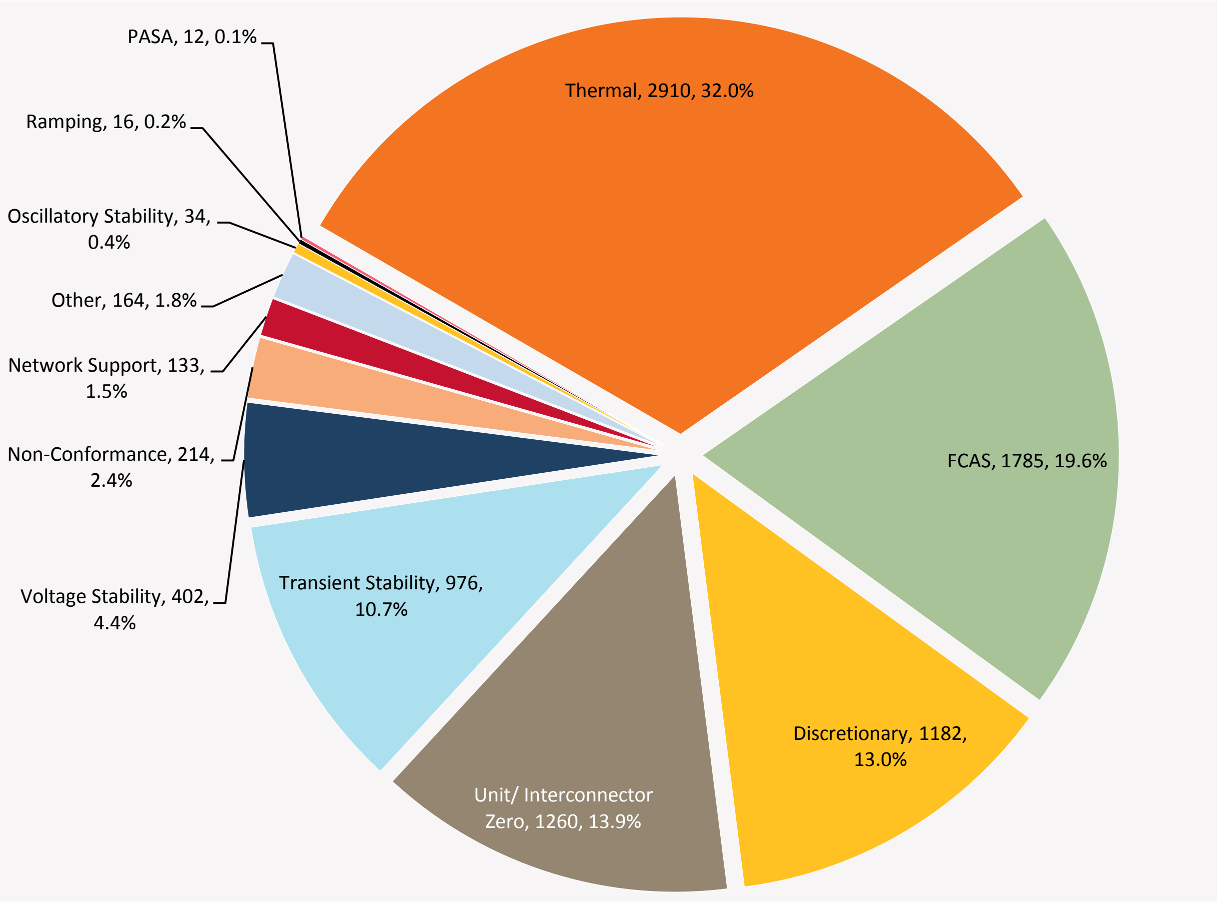
Ad hoc constraint equations are also created by AEMO's control room staff. These are mainly created for a large number of LHS terms. The software that creates quick constraints now handles more complex LHSs, so ad hoc constraint equations are rarely built.

In Figure 1-2, "other" combines the constraint equations with the following limit types: Quality of Supply, Islanding–Unit, Region Separation, Negative Residue, Default, and ROC Frequency. Similarly "Unit/Interconnector Zero" combines the limit types Unit Zero–FCAS, Unit Zero, and "Interconnector Zero".

Compared to 2012, there were only a few changes to the breakup of the constraint equations in 2013. These differences were:

- Tasmania increased from 521 to 672.
- South Australia increased from 754 to 1,146.
- Total thermal constraint equations increased from 2,372 to 2,910. This is attributed to the increase in South Australian constraint equations.

Figure 1-2 — Constraint equations by limit type



2. CONSTRAINT EQUATION CHANGES

This chapter examines the power system and constraint equation changes. One of the main drivers for constraint equation changes is power system change, i.e., the addition or removal of plant (either generation or transmission). The addition of a new generator to either the LHS or RHS of a constraint equation can cause multiple constraint equation changes.

The tables in this chapter list transmission system and generator changes separately. Only changes on the main transmission system are listed; these normally cause direct changes to the constraint equations.

In 2013, the number of generator and transmission changes was the highest since 2009. This led to the largest number of constraint equation changes since 2010.

2.1. Generators added or removed in 2013

The following list includes all scheduled and semi-scheduled generators added to or removed from the power system in 2013. It also lists non-scheduled plant large enough to have caused constraint equation changes.

Unlike the past several years, 2013 saw generator changes in every National Electricity Market (NEM) region. Five new wind farms were registered across the southern regions along with seven existing generator de-registrations in Queensland. This was similar to the number of new registrations in 2010 and 2011 though still lower than 2009. (There were 13 in 2009, four in 2010, five in 2011, and two in 2012).

Table 2-1 — Generator changes in 2013

Generator	Registration Date	Region	Notes
Collinsville Unit 1	1 January 2013	Qld	Deregistered Generator
Collinsville Unit 2	1 January 2013	Qld	Deregistered Generator
Collinsville Unit 3	1 January 2013	Qld	Deregistered Generator
Collinsville Unit 4	1 January 2013	Qld	Deregistered Generator
Collinsville Unit 5	1 January 2013	Qld	Deregistered Generator
Musselroe Wind Farm	11 March 2013	Tas	New Generator
Swanbank B Unit 1	13 August 2013	Qld	Deregistered Generator
Swanbank B Unit 3	13 August 2013	Qld	Deregistered Generator
Snowtown South Wind Farm	10 September 2013	SA	New Generator
Snowtown North Wind Farm	10 September 2013	SA	New Generator
Mt Mercer Wind Farm	15 October 2013	Vic	New Generator
Gullen Range	19 November 2013	NSW	New Generator

2.2. Transmission changes in 2013

From 2009 to 2012 the number of transmission changes did not vary greatly (there were 19 in 2012, 21 in 2011, 17 in 2010, and 21 in 2009). However, there was an increase in 2013, with 28 changes. The most significant changes impacting constraint equations were the cut-in of 275 kV lines from Tarong to Halys and the commissioning of the two Calvale to Stanwell 275 kV lines.

Similar to previous years, most of the transmission changes were in Queensland.

Table 2-2 – Transmission changes in 2013

Generator	Registration Date	Region	Notes
Ballina to Lennox Head (9G2) 66 kV line	1 Feb 2013	NSW	Line constructed at 132 kV but initially operated at 66 kV.
Canberra to Williamsdale (3C) 330 kV line	22 Feb 2013	NSW	Upgraded section of Canberra to Cooma 132 kV lines to 330 kV. New 330/132 kV substation at Williamsdale.
Blackwall to Greenbank (8819) 275 kV line	18 Mar 2013	Qld	The new line replaces the Swanbank to Blackwall (8819) and Greenbank to Swanbank (806) 275 kV lines. Part of the Swanbank 275 kV switchyard decommissioning.
Tully to Cardwell (7389) 132 kV line	11 Apr 2013	Qld	Replacement for decommissioned line constructed at 275 kV running at 132 kV.
Whyalla Central substation	16 May 2013	SA	Whyalla Central substation was cut in to the former Davenport to Whyalla Terminal No.1 132 kV line
Columboola to Wandoan South (7394 and 7395) 132 kV lines	6 Jun 2013	Qld	New lines connected to new Wandoan South substation. Lines constructed at 275 kV.
Calvale to Halys (8811) 275 kV line	27 Jun 2013	Qld	The old Calvale to Tarong (8811) 275 kV line now terminates at Halys forming the new Calvale to Halys (8811) 275 kV Line.
Cultana substation No.2 275/132 kV transformer	11 Jul 2013	SA	
Halys to Tarong (8869) 275 kV line	12 Jul 2013	Qld	Calvale to Tarong (8810) 275 kV line cut into Halys.
Calvale to Halys (8810) 275 kV line	24 Jul 2013	Qld	Calvale to Tarong (8810) 275 kV line cut into Halys.
Halys to Calvale (8868) 275 kV line	2 Aug 2013	Qld	Calvale to Tarong (8810) 275kV line cut into Halys.
Cultana to Davenport No. 2 275 kV line	7 Aug 2013	SA	
Braemar to Halys (8815) 275 kV line	4 Sept 2013	Qld	Braemar to Tarong (8815) 275 kV line cut into Halys.
Halys to Tarong (8871) 275 kV line	13 Sept 2013	Qld	Braemar to Tarong (8815) 275 kV line cut into Halys.
Blyth West 275 kV substation	14 Sept 2013	SA	Cut into existing Bungama to Para 275 kV line.
Braemar to Halys (8814) 275 kV line	26 Sept 2013	Qld	Braemar to Tarong (8814) 275 kV line cut into Halys.
Blyth West to Snowtown 2 WF 275 kV line	27 Sept 2013	SA	
Halys to Tarong (8870) 275 kV line	4 Oct 2013	Qld	Braemar to Tarong (8814) 275 kV line cut into Halys.
Bannaby to Gullen Range (61) 330 kV line	4 Oct 2013	NSW	Bannaby to Yass (61) 330 kV line cut into Gullen Range.
Gullen Range to Yass (3J) 330 kV line	4 Oct 2013	NSW	Bannaby to Yass (61) 330 kV line cut into Gullen Range.
Gullen Range A and B 330 kV buses	4 Oct 2013	NSW	
Cardwell to Ingham South (7388) 132 kV line	23 Oct 2013	Qld	
Calvale to Stanwell (8874) 275 kV line	25 Oct2013	Qld	
Elaine Terminal station	27 Oct2013	VIC	Cut-in to existing Ballarat to Moorabool No.2 220 kV line.
Tully to Yabulu South (7132) 132 kV line	31 Oct 2013	Qld	
Calvale to Stanwell (8873) 275 kV line	5 November 2013	Qld	
Elaine Terminal Station (ELTS) 220/132 kV (R2) transformer	8 Nov 2013	Vic	
Cultana No.1 275/132 kV transformer	26 Nov 2013	SA	

2.3. Constraint equation changes comparison

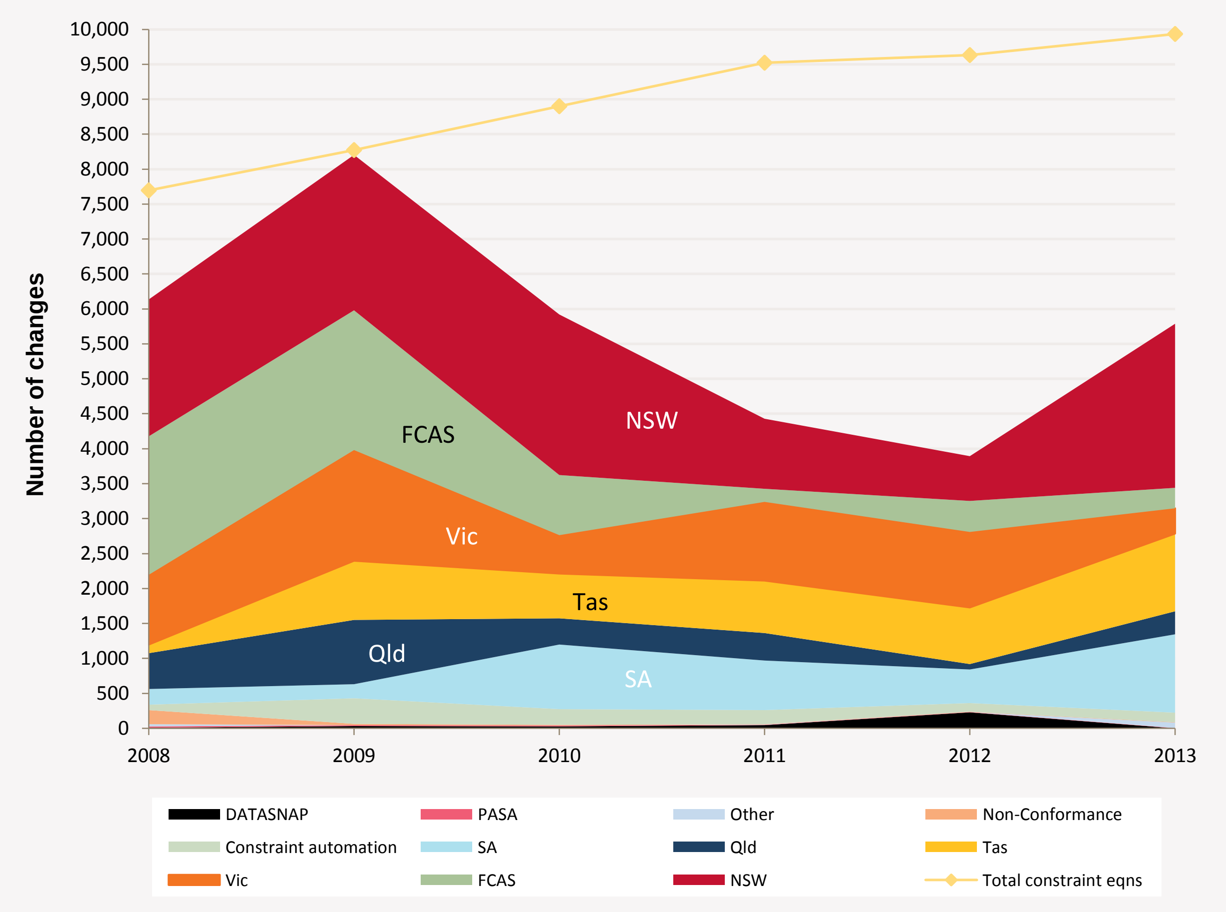
Figure 2-1 compares annual and monthly constraint equation changes. It includes a comparison of the total number of constraint equations at the end of each calendar year.

It does 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 simple description fixes; some are more complex and require several days of work).

These results measure when the changes occurred, not when they became active, so the FCAS change that was made active on 1 Jan 2009 but loaded into the database in late-2008 is included in the 2008 results, not the 2009 results.

The number of changes for 2013 does not include changes due to the constraint violation penalty factor (CVP) update in August 2013[4], which required 8,833 constraint equation updates. Nor does it include the changes due to the real time constraint automation.[5]

Figure 2-1 – Constraint equation changes per calendar year, 2008 to 2013



As shown in Figure 2-1, the number of constraint changes in 2013 (5,871) was the first increase since 2009. In 2013, three regions dominated the changes: 40% were in New South Wales, 19% were in South Australia, and 19% were in Tasmania.

[4] AEMO. *Schedule of CVP Factors*. Available at: http://www.aemo.com.au/Electricity/Market-Operations/Dispatch/Schedule-of-Constraint-Violation-Penalty-Factors. Viewed on: 17 Feb 2014.

[5] AEMO. *Constraint Automation – Closing the Loop - Discussion Paper*. Available at: http://www.aemo.com.au/Electricity/Market-Operations/Congestion-Information-Resource/Constraint-Automation-Closing-the-Loop-Discussion-Paper. Viewed on: 17 Feb 2014.

The number of changes in 2013 was slightly above the 10-year average of 5,500 changes and similar to 2006, 2008, and 2010 (6,196, 6,343, and 6,250 respectively). The volume of constraint equation changes in these years was due to:

- The program to convert constraint equations to “fully co-optimised” in 2006.
- The Snowy region abolition in 2008.
- Multiple stages of the New South Wales western 500 kV project in 2009 and part of 2010.
- Changes across multiple regions in 2013. The constraint equation operating margins[6] were reviewed in early 2013, resulting in a large number of changes in New South Wales and South Australia. The new Gullen Range Wind Farm generated changes in New South Wales as did the Musselroe Wind Farm in Tasmania.

The low number of FCAS constraint equation changes in 2013 is due to lack of power system or market changes impacting FCAS. The large number of changes in previous years was due to regulation co-optimisation and five-minute services (2008), Snowy abolition (2008), and Tasmanian frequency operating standards changing (2009).

[6] AEMO. *Confidence Levels, Offsets & Operating Margins*. Available at: http://www.aemo.com.au/Electricity/Resources/Working-Groups/Confidence-Levels-Offsets-and-Operating-Margins. Viewed on: 17 Feb 2014.

3. BINDING

This chapter examines the top 20 binding constraint equations in 2013. A constraint equation is binding when power system flows managed by it have reached the applicable thermal or stability limit or the constraint equation is setting an FCAS requirement. When a constraint equation is binding NEMDE has changed generator and interconnector targets so to satisfy the constraint equation – this has a market impact (see chapter 4).

System normal constraint equations are bolded and the number of hours for 2012 (if any) is indicated in brackets below the 2013 hours. The tables contain a brief description of the constraint equation (in italics) along with any comments.

Full descriptions, or LHS and RHS of the constraint equations can be obtained from either the plain English converter[7] or via the MMS data model.[8]

As there is at least one constraint equation setting the requirement for each of the eight FCAS services at any time, this leads to many more hours of binding for FCAS constraint equations. These would dominate the top 20, so the FCAS and network binding results are separated into two tables (see Table 3-1 and Table 3-2 below).

Some constraint equations only bind at certain times of the year (such as winter or summer); Figure 3-1 shows a monthly breakdown 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 represented by several constraint equations to either:

- Move each generator from a maximum calculation onto the LHS of separate constraint equations (such as the New South Wales to Queensland voltage stability limit).
- Manage the same limit under different network configurations (such as Yallourn W1 switched into 500 kV or 220 kV mode).
- Combine different values of network support for the same generator(s).

Most of the top 20 binding results listed in Table 3-1 and Table 3-2 below are system normal constraint equations and not those for outage cases.

3.1. Network constraint equations

Table 3-1 – Top 20 binding network constraint equations

Constraint Equation ID (System Normal Bold)	2013 Hours (2012 Hours)	*Description* Notes
N_X_MBTE_3A & N_X_MBTE_3B	3,773 (503)	*Out = all three Directlink cables* All three Directlink cables were out for 158.1 days in 2013 compared to 20.9 days in 2012. See Table 6
#MUSSELR1_E	1,107 (0)	*Quick constraint equation to limit Musselroe to various levels* This constraint equation was invoked in 2013 for Musselroe Wind Farm commissioning.
V>S_NIL_HYTX_HYTX	992 (48)	*Out = Nil, avoid overloading the remaining Heywood 275/500 kV transformer on trip of one Heywood 275/500 kV transformer* With the update to the V^^S_NIL_MAXG_xxx constraint equations in January 2013 this constraint equation is now more likely to bind. AEMO expects this will bind at similar levels until the Heywood upgrade in mid-2016.

[7] Available at: https://mms.prod.nemnet.net.au/Mms/login.aspx.
[8] Available at: http://www.aemo.com.au/About-the-Industry/Information-Systems/Data-Interchange.

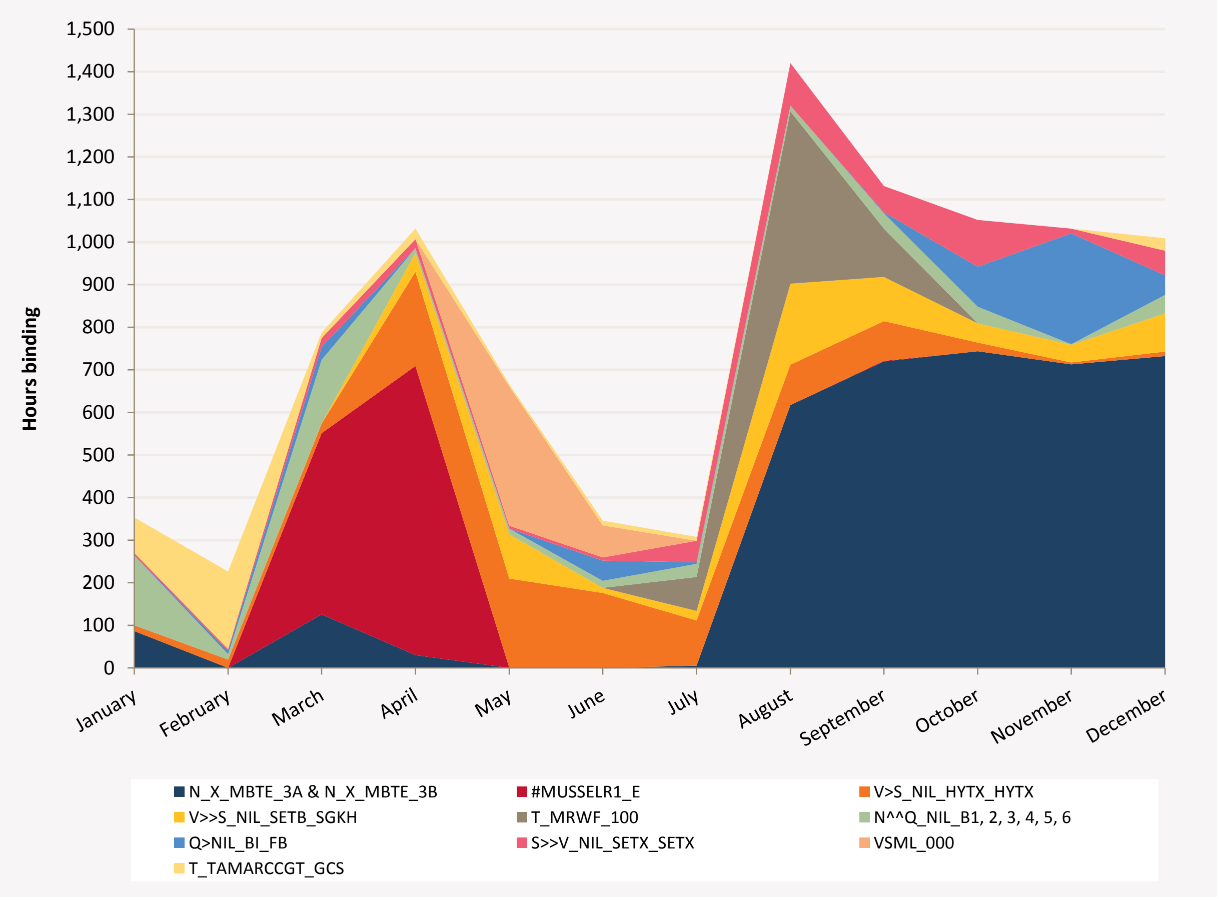
Constraint Equation ID (System Normal Bold)	2013 Hours (2012 Hours)	*Description* Notes
V>>S_NIL_SETB_SGKH	652 (0)	*Out = Nil, avoid overloading Snuggery to Keith 132 kV line on trip of a South East to Tailem Bend 275 kV line* This will bind for high import into SA with high levels of generation from the wind farms and gas turbines in the south east. With a revised rating provided in December 2013 AEMO expects this constraint equation to bind less in 2014.
T_MRWF_100	597 (0)	*Discretionary 100 MW upper limit on Musselroe Wind Farm* This constraint equation was invoked in 2013 for the Musselroe Wind Farm commissioning. This constraint equation was invoked for a total of 73.6 days in 2013. See Table 6
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	531 (103)	*Out = Nil, avoid voltage collapse for loss of the largest Qld generator* This voltage collapse limit is split into seven constraint equations to co-optimise with each of the six largest generators in Qld. Overall N^^Q_NIL_B1 (for trip of Kogan Creek) binds for the most number of intervals.
Q>NIL_BI_FB	493 (484)	*Out = Nil, avoid overloading on Boyne Island feeder bushing on Calliope Rover to Boyne Island 132 kV lines, for the contingent loss of a single Calliope River to Boyne Island 132 kV line*
S>>V_NIL_SETX_SETX	456 (444)	*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 SA to Vic and high generation from the wind farms and gas turbines in the south east of SA.
VSML_ZERO	424 (33)	*Vic to SA on Murraylink upper transfer limit of 0 MW* This constraint equation is normally invoked for Murraylink out of service. This constraint equation was invoked for 27.2 days in 2013 compared to 13.8 days in 2012. See Table 6.
T_TAMARCCGT_GCS	358 (911)	*Limit output of Tamar Valley Power Station based on load available for shedding by Tamar Valley 220 kV generation control scheme (GCS)* The Tamar Valley output is dependent on the GCS so AEMO expects that this constraint equation will bind for a high number of hours in 2014.
T>T_NIL_BL_IMP_5F	327 (27)	*Out = Nil, avoid overloading Hadspen to Georgetown No.1 220 kV line (flow to North) for trip of the Hadspen to Georgetown No.2 220 kV line with no SPS action* This constraint only binds when the NCSPS[9] control scheme is unavailable.
V>S_460	301(15)	*VIC to SA on Heywood upper transfer limit of 460 MW* An update to the V^^S_NIL_MAXG_xxx constraint equations in January 2013 mean this constraint equation is now more likely to bind. AEMO expects this will bind at similar levels until the Heywood upgrade in mid-2016.
T>T_NIL_BL_IMP_1B	300 (5)	*Out = Nil, avoid overloading either Gordon to Chapel St 220 kV line for trip of the other Gordon to Chapel St 220 kV line with no SPS action* This constraint equation binds at times of high Gordon generation when the NCSPS control scheme is unavailable.
NSA_Q_GSTONE34_xxx	284 (367)	*Gladstone 3 + 4 >= various levels for Network Support Agreement* The binding results from three constraint equations that set the minimum level of Gladstone 3 and 4 generation have been combined.

[9] Network control system protection scheme.

Constraint Equation ID (System Normal Bold)	2013 Hours (2012 Hours)	*Description* Notes
Q>>NIL_855_871	278 (279)	*Out = Nil, avoid overload on Calvale to Wurdong (871) 275 kV line on trip of Calvale to Stanwell (855) 275 kV line* This constraint equation has been removed following the construction of the new double circuit 275 kV lines between Calvale and Stanwell (8873 and 8874) in late 2013.[10]
T_MRWF_QLIM_xx	217 (0)	*Out = Nil, limit Musselroe Wind Farm based on status of the reactive plant at Musselroe Wind Farm* The binding results from the six constraint equations have been combined.
V^^S_NIL_MAXG_xxx	209 (240)	*Out = Nil, Vic to SA long term voltage stability limit for loss of the largest credible generation contingency in SA, South East capacitor bank on/off* There are two constraint equations that make up the voltage stability export limit from Vic to SA and all the binding results have been combined.
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	202 (164)	*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. AEMO expects that the combination of these three constraint equations will bind for a similar amount in 2014.
N_X_MBTE2_A & N_X_MBTE2_B	196 (483)	*Out = two Directlink cables* Two Directlink cables were out for 214.9 days in 2013 compared to 60.0 days in 2012. See Table 6.
T>T_NIL_110_1	189 (0)	*Out = Nil, avoid overloading the Derby to Scottsdale Tee 110 kV line on no line trips* This constraint equation was implemented in mid-2013 with the Musselroe Wind Farm commissioning. It binds with high output from Musselroe.

[10] Powerlink. *Calvale to Stanwell.* Available at: http://www.powerlink.com.au/Projects/Central/Calvale_to_Stanwell.aspx. Viewed on: 18 Feb 2014.

Figure 3-1 – Top 10 binding constraint equations per month



3.2. Frequency Control Ancillary Service

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. The Basslink trip constraint equations (such as F_T+NIL_BL_R6_1) only bind when Basslink is transferring into Tasmania, so the binding hours reflect this.

Table 3-2 – Top 20 binding FCAS constraint equations

Constraint Equation ID (System Normal Bold)	2013 Hours (2012 Hours)	*Description* Notes
F_I+NIL_MG_R5	7,086 (7,498)	*NEM raise 5-minute requirement for a NEM generation event* The largest unit is usually Kogan Creek or one of the large NSW units.
F_I+NIL_MG_R6	6,285 (6,375)	*NEM raise 6-second requirement for a NEM generation event*
F_I+NIL_MG_R60	6,256 (6,280)	*NEM raise 60-second requirement for a NEM generation event*
F_I+ML_L5_0400	5,982 (5,999)	*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_I+NIL_DYN_LREG	5,354 (6,618)	*NEM lower regulation requirement*

Constraint Equation ID (System Normal Bold)	2013 Hours (2012 Hours)	*Description* Notes
F_T++NIL_TL_L60	5,130 (4,007)	*Tasmania lower 60-second requirement for loss of two Comalco potlines, Basslink able to transfer FCAS*
F_T++NIL_TL_L6	4,629 (3,470)	*Tasmania lower 6-second requirement for loss of two Comalco potlines, Basslink able to transfer FCAS*
F_I+ML_L6_0400	3,416 (1,962)	*NEM lower 6-second requirement for a NEM load event*
F_MAIN++NIL_MG_R60	2,424 (2,655)	*Mainland raise 60-second requirement for a mainland generation event, Basslink able transfer FCAS*
F_I+APHY_L5	1,949 (1,494)	*Out = Alcoa Portland to Heywood 500 kV line, NEM lower 5-minute requirement for the loss of the other Alcoa Portland to Heywood 500 kV line* One Alcoa to Portland 500 kV line was out for 87.7 days in 2013 compared to 75.4 days in 2012 - see Table 6.
F_I+NIL_DYN_RREG	1,880 (1,615)	*NEM raise regulation requirement*
F_I+ML_L60_0400	1,610 (934)	*NEM lower 60-second requirement for a NEM load event*
F_MAIN++NIL_MG_R6	1,548 (2,256)	*Mainland raise 6-second requirement for a mainland generation event, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R5	1,466 (1,729)	*Mainland raise 5-minute requirement for a mainland generation event, Basslink able transfer FCAS*
F_T++NIL_TL_L5	1,439 (610)	*Tasmania lower 5-minute requirement for loss of two Comalco potlines, Basslink able to transfer FCAS*
F_I+APHY_L60	1,039 (718)	*Out = Heywood to Alcoa Portland 500kV line, lower 60 second requirement* See comment on F_I+APHY_L5 above.
F_T++LREG_0050	926 (636)	*Tasmania lower regulation requirement greater than 50 MW, Basslink able transfer FCAS*
F_MAIN++ML_L5_0400	837 (1,693)	*Mainland lower 5-minute requirement for a mainland load event, Basslink able transfer FCAS*
F_T+NIL_TL_L60	760 (688)	*Out = Nil, Tasmania Lower 60-second requirement for loss of two Comalco potlines, Basslink unable to transfer FCAS*
F_T+NIL_TL_L6	760 (699)	*Tasmania lower 6-second requirement for loss of two Comalco potlines, Basslink unable to transfer FCAS*

3.3. Binding Trends

Figure 3-2, Figure 3-3 and Figure 3-4 show the binding constraint equations categorised by region, limit type, and system normal/outage for the past six years. The FCAS in Figure 3-3 excludes the system normal FCAS constraint equations (as these would dominate the graph). Binding FCAS hours (whether system normal or outage) are excluded from Figure 3-4 for the same reason.

The three graphs below indicated the following trends:

- Total binding hours decreased from 2008 to 2012 with the exception of a peak in 2010. Total binding hours in 2013 were the second highest since 2008.

- New South Wales and South Australia's binding hours increased from 2008 to 2012; however, New South Wales increased significantly in 2013. The increase in New South Wales can be attributed to the increase in binding intervals for the New South Wales to Queensland voltage stability and Directlink constraint equations.
- Queensland and Victoria's binding hours have decreased since 2008, although there was an increase for Queensland in 2010.
- Tasmania's binding hours have increased since 2008; however, the 2011 totals were less than 2009.
- Voltage stability constraint equations are binding at higher levels compared to 2008 (512 hours versus 1585 hours in 2013), and lower than the 2011 peak of 2091.
- Thermal overload constraint equations bound for 6,633 hours in 2013; the highest since 2005.
- Transient stability binding constraint equations increased steadily from 469 hours in 2007 to 1,618 in 2011, spiking at 2,243 in 2010. The 2013 binding hours were much lower, at 171, mainly attributed to the reduced binding hours of the Victoria to New South Wales transient stability constraint equations.
- Binding hours in 2013 due to Directlink cable outages were the highest since 2008 at 3,970 hours.
- Overall binding hours (excluding FCAS) in 2013 were the highest since 2007.
- System normal binding hours have been declining since the 2008 peak of 9,756. However, in 2013 these increased to 7,521 hours (similar to 2010). Even with this increase, the outage binding hours, also in decline since 2008, nearly doubled to 8,708 hours. This meant for the first time since 2007 the number of outage binding hours was larger than system normal.

Figure 3-2 – Binding constraint equations by region

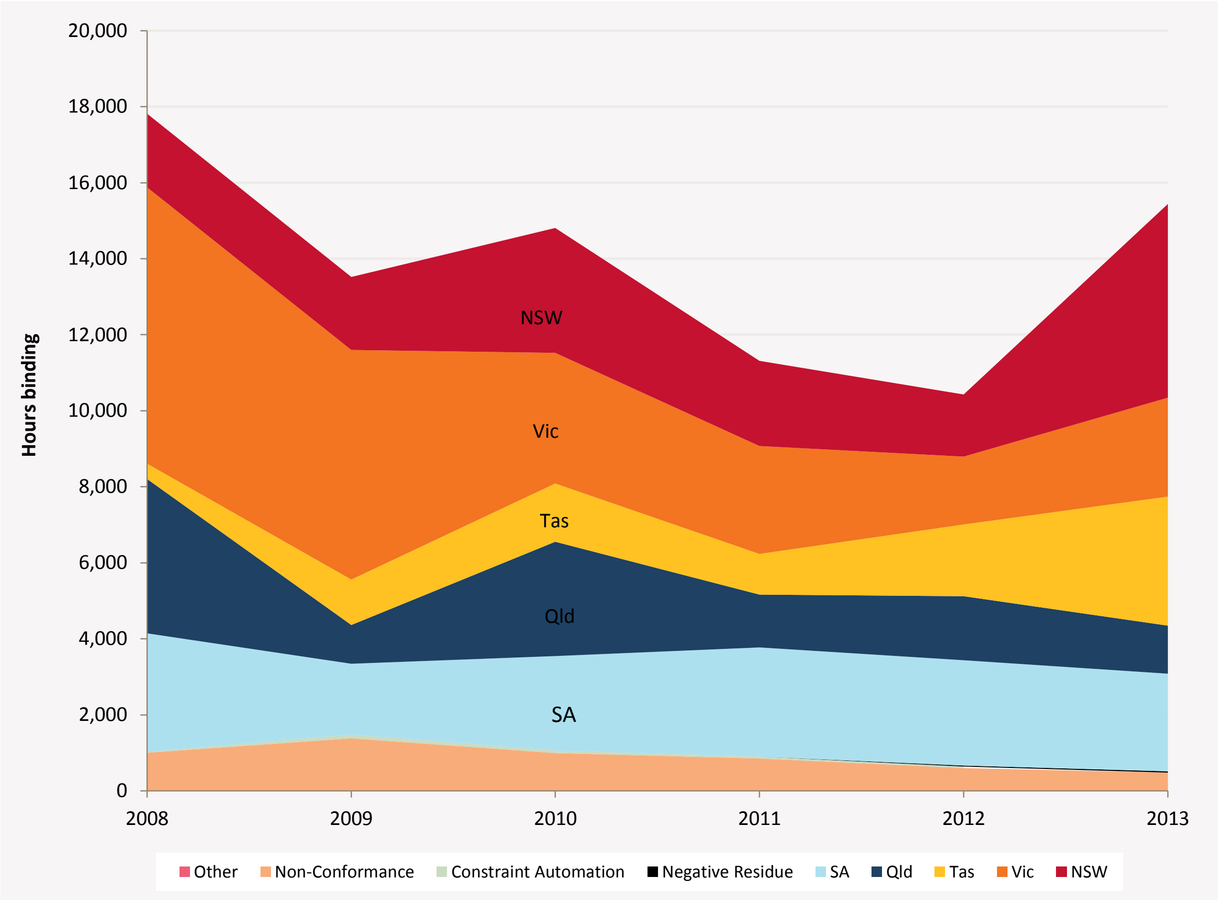


Figure 3-3 – Binding constraint equations by limit type

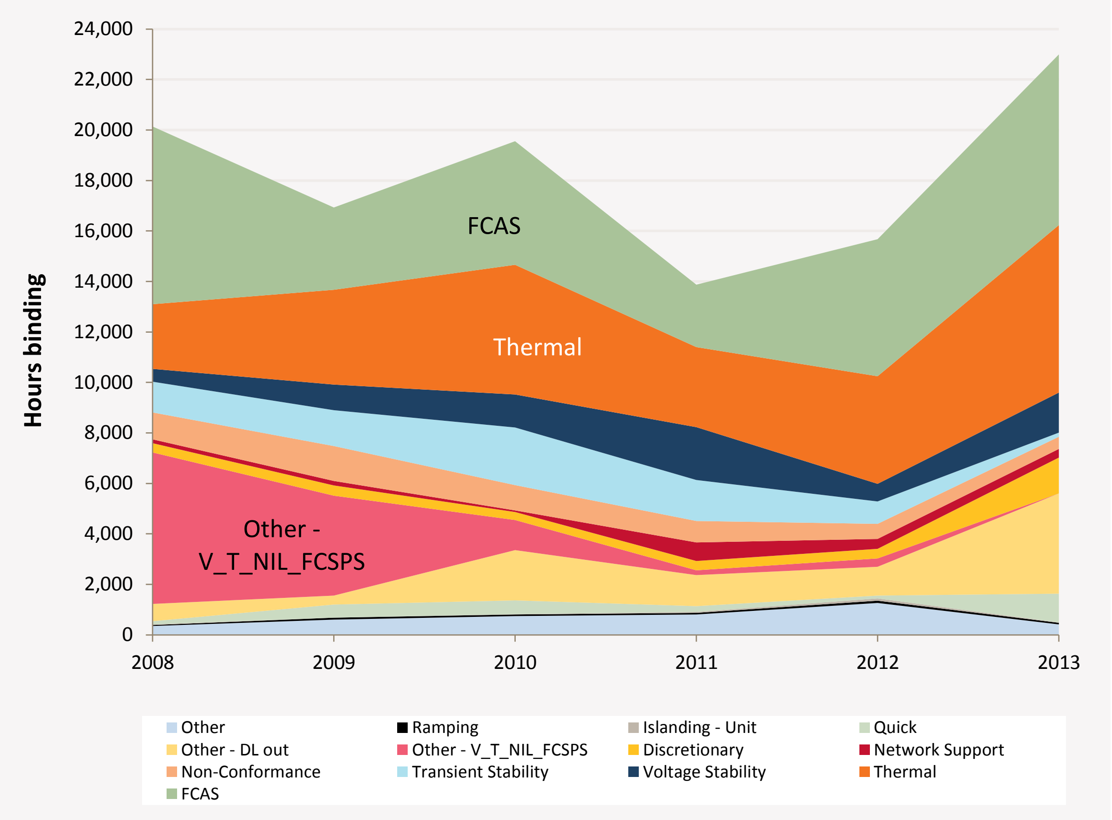
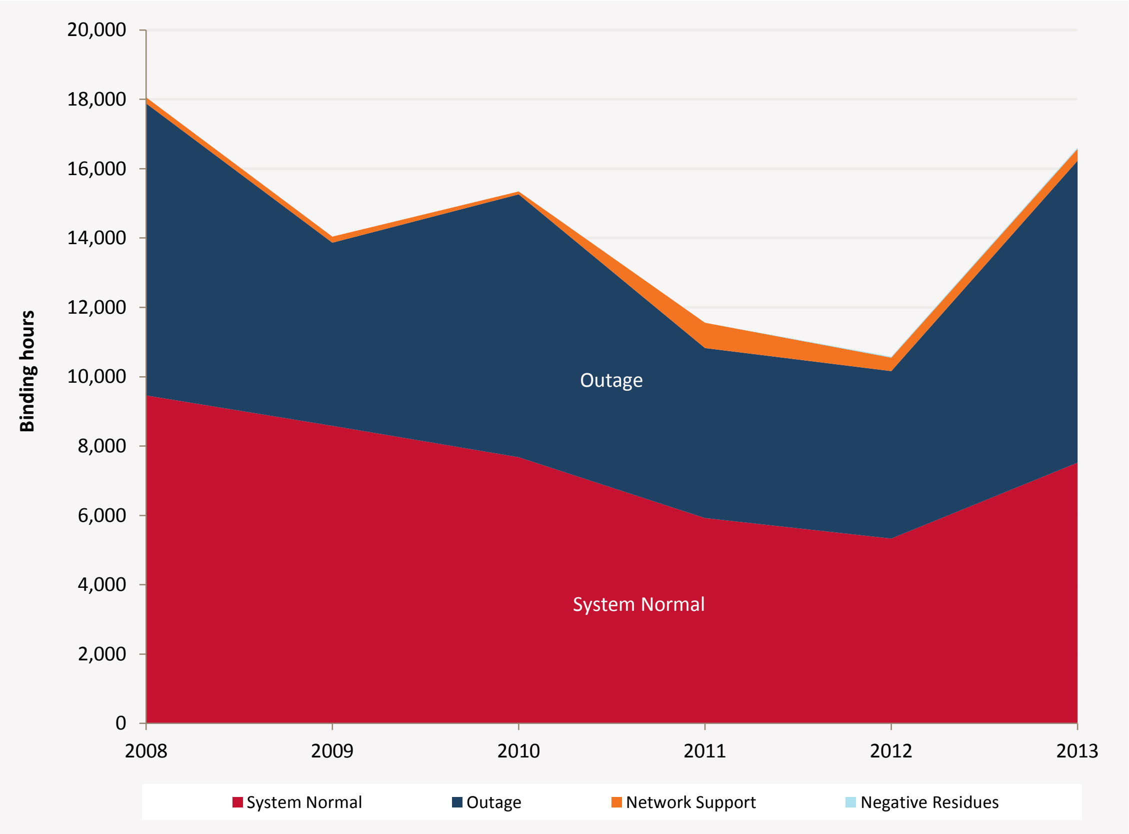


Figure 3-4 – Binding hours for system normal and outages



4. MARKET IMPACT

This chapter compares constraint equations by their by their impact on electricity market pricing. Their market impact is determined by summating the marginal values from the marginal constraint cost (MCC) re-run. This re-run relaxes any violating constraint equations and constraint equations with a marginal value equal to the constraint equation's CVP x market price cap (MPC).

The calculation caps the marginal value in each dispatch interval at the MPC value that is valid on that date (the MPC was increased to $13,100 on 1 July 2013).

Similar to the binding constraint equations in Table 3-1 and Table 3-2, Table 4-1 indicates system normal constraint equations in bold and the number of binding hours for 2012 is indicated in brackets below the 2013 hours. The 2012 summated marginal values are in brackets below the 2013 hours.

The constraint equations NSA_Q_BARCALDN, NSA_Q_GSTONE34_xxx, NSA_S_PORxxx, T_MRWF_100, T_MRWF_120 all relate to the output of one or two generators greater than or equal to the RHS. These are either for network support from a generator or an outage of the radial transmission line connecting to the unit. While it appears they have a large market impact, this is more due to the bidding of the individual generator.

Table 4-1 – Top 20 market impact constraint equations in 2013

Constraint Equation ID (System Normal Bold)	2013 ∑MARGINAL VALUES (2012 ∑MARGINAL VALUES)	2013 Hours (2012 Hours)	*Description* Notes
T_MRWF_100	$7,481,617 (0)	597.1 (0)	*Discretionary 100 MW upper limit on Musselroe Wind Farm* See Table 3 for comments
T_MRWF_QLIM_xx	$2,720,517 (0)	217.3 (0)	*Out = Nil, limit Musselroe Wind Farm based on status of the DVARs, capacitor banks or synchronous condensers at Musselroe* See Table 3 for comments
Q>>NIL_855_871	$2,435,502 ($1,431,065)	277.8 (278.6)	*Out = Nil, avoid overload on Calvale to Wurdong (871) 275 kV line on trip of Calvale to Stanwell (855) 275 kV line* See Table 3 for comments
T>T_NIL_110_1	$2,345,388 (0)	188.5 (0)	*Out = Nil, avoid overloading the Derby to Scottsdale Tee 110 kV line on no line trips* See Table 3 for comments
NSA_Q_BARCALDN	$1,856,454 ($1,436,430)	29.5 (17.7)	*Network Support Agreement for Barcaldine GT to meet local islanded demand at Clermont and Barcaldine for the outage of Clermont to Lilyvale (7153) 132 kV line* This constraint equation is used for planned outages of the Clermont to Lilyvale (7153) or Barcaldine to Clermont (7154) 132 kV lines
NSA_S_PORxxx	$1,796,463 ($0)	19.4 (0.1)	*Network Support Agreement for Port Lincoln Units 1 and 2*
NSA_Q_GSTONE34_xxx	$1,759,776 ($11,981,412)	283.7 (366.3)	*Gladstone 3 + 4 >= various levels for Network Support Agreement* See Table 3 for comments

Constraint Equation ID (System Normal Bold)	2013 ∑MARGINAL VALUES (2012 ∑MARGINAL VALUES)	2013 Hours (2012 Hours)	*Description* Notes
Q>NIL_TR_TX1_4	$1,479,171 ($312,478)	120.7 (25.8)	*Out = Nil, avoid overloading a Tarong 275/132 kV transformer (No.1 or No.4) on trip of the other Tarong 275/132 kV transformer (No.1 or No.4)*
T_MRWF_120	$1,340,400 (0)	107.8 (0)	*Discretionary 120 MW upper limit on Musselroe Wind Farm* This constraint equation was invoked in 2013 for the commissioning of the Musselroe wind farm.
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	$898,361 (0)	531.3 (0)	*Out = Nil, avoid voltage collapse for loss of the largest Queensland generator* See Table 3 for comments
T_TAMARCCGT_GCS	$877,585 ($214,829)	357.7 (911.3)	*Limit output of Tamar Valley Power Station based on load available for shedding by Tamar Valley 220 kV generation control scheme (GCS)* See Table 3 for comments
V>S_NIL_HYTX_HYTX	$804,155 ($3,682)	990.8 (48.4)	*Out = Nil, avoid overloading the remaining Heywood 275/500 kV transformer on trip of one Heywood 275/500 kV transformer* See Table 3 for comments
VTBL_ROC	$748,573 ($20,456)	14.3 (22.3)	*Out = Nil, rate of change (Victoria to Tasmania) limit (200 MW/5 minute) for Basslink*
VSML_ZERO	$641,565 ($961)	424.2 (30.0)	*Victoria to South Australia on Murraylink upper transfer limit of 0 MW* See Table 3 for comments
V>>SML_NIL_8	$593,900 ($14)	29.3 (0.3)	*Out = Nil, avoid overloading Ballarat to Bendigo 220 kV line for loss of Shepparton to Bendigo 220 kV line* This constraint equation binds during periods of high demands in the Victorian state grid (220 kV system in northern western Victoria) and for periods when Murraylink is constrained from SA to Vic (mainly due to S>V_NIL_NIL_RBNW). AEMO expects this constraint equation to bind during summer until the regional Victorian thermal upgrade is completed.[11]
V>>S_NIL_SETB_SGKH	$533,537(0)	652.1(0)	*Out = Nil, avoid overloading Snuggery to Keith 132 kV line on trip of a South East to Tailem Bend 275 kV line* See Table 3 for comments
S>V_NIL_NIL_RBNW	$433,772 ($113,505)	51.7 (69.4)	*Out = Nil, avoid overloading the North West Bend to Robertstown 132 kV line on no line trips* This constraint equation normally sets the upper limit on Murraylink and is expected to continue to bind for a similar amount in 2014.

[11] AEMO. *Regional Victorian Thermal Capacity Upgrade*. Available at: http://aemo.com.au/Electricity/Planning/Regulatory-Investment-Tests-for-Transmission/Regional-Victorian-Thermal-Capacity-Upgrade. Viewed on: 10 Feb 2014.

Constraint Equation ID (System Normal Bold)	**2013 ∑MARGINAL VALUES (2012 ∑MARGINAL VALUES)**	**2013 Hours (2012 Hours)**	***Description*** **Notes**
N>N-NIL_LSDU	\$325,000 (\$115,282)	159.6 (62.0)	*Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) 132 kV line on trip of the other Lismore to Dunoon line (9U7 or 9U6) 132 kV line* This constraint equation binds for high exports from NSW to Qld.
F_T+LREG_0050	\$323,429 (\$9,899)	622.6 (520.1)	*Tasmania lower regulation requirement greater than 50 MW, Basslink unable to transfer FCAS*
N_X_MBTE_3A & N_X_MBTE_3B	\$318,168 (\$39,316)	3,772.9 (503.1)	*Out = all three Directlink cables* See Table 3 for comments

4.1. Market Impact Trends

There was a steady decrease in market impacts from 2009[12] to 2011 due to binding constraint equations (see Figure 4-1). The notable exception was Queensland, where market impacts increased over the same period; this was the primary cause for the market impact increase in 2012. The market impact increased in 2012 and 2013 to higher levels than 2009.

The main cause of the high 2013 market impact was the significant increase in Tasmania. This can be attributed to the high market impact of the constraint equations associated with the commissioning of the Musselroe Wind Farm (see Table 4-1).

[12] The MCC data is only available from July 2008 onwards so only the calendar years after 2009 are examined.

Figure 4-1 – Market impact by region

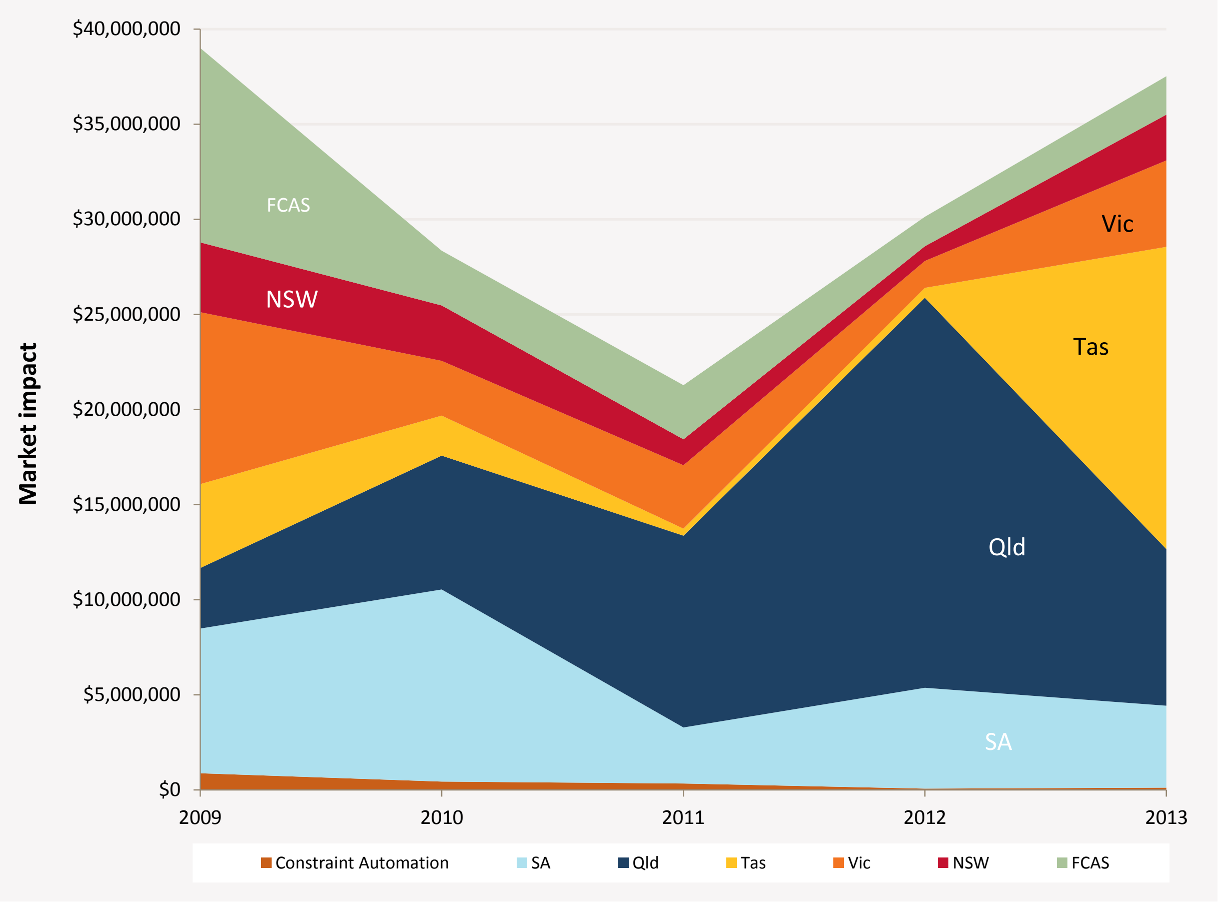
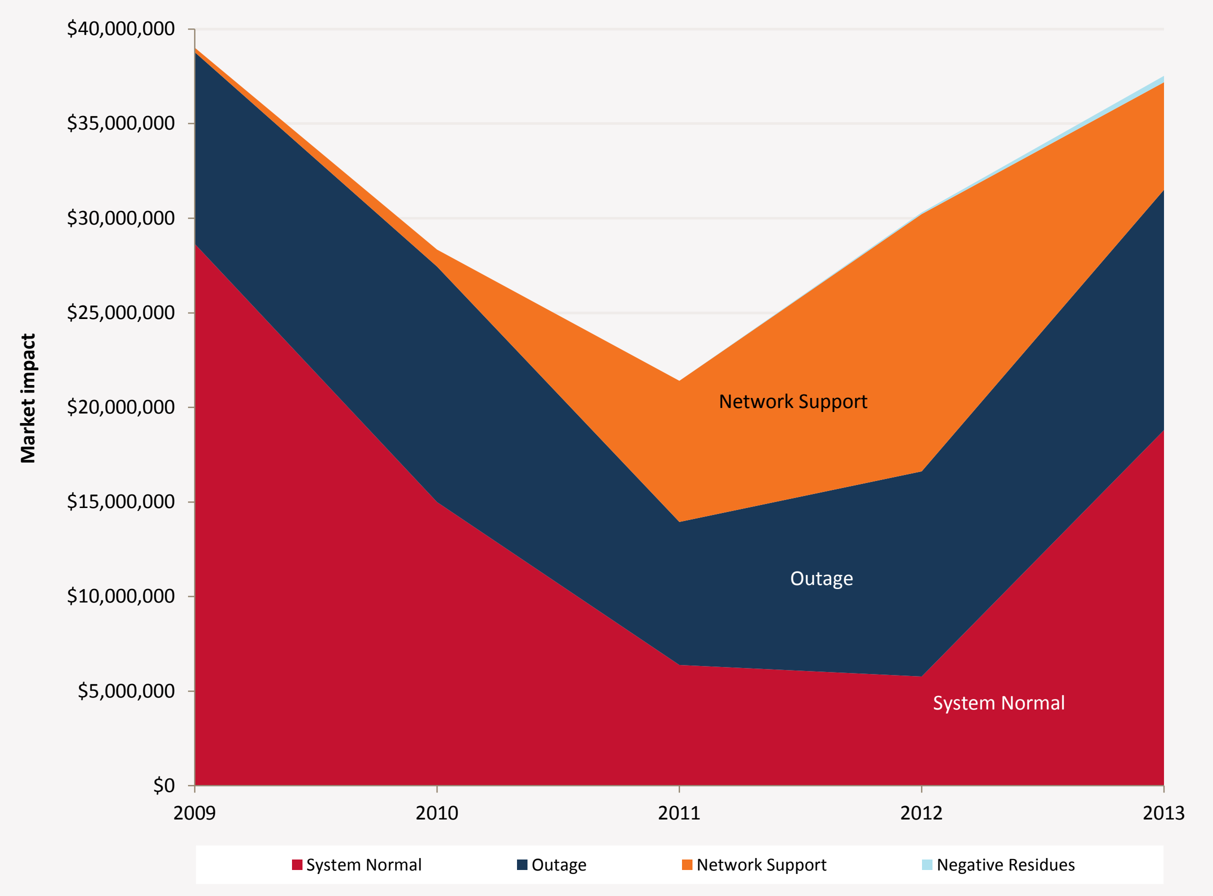


Figure 4-2 shows that while the market impact of outages has been fairly stable since 2010, the system normal impact has changed considerably. The market impact due to system normal constraint equations decreased steadily from 2009 to 2011, was stable in 2012, and increased sharply in 2013. The main cause of the 2013 increase was the new system normal constraint equations associated with Musselroe Wind Farm (T_MRWF_QLIM_xx and T>T_NIL_110_1).

Figure 4-2 – Market impact for system normal and outages



5. CONSTRAINT EQUATIONS SETTING INTERCONNECTOR LIMITS

This chapter examines each of the NEM interconnectors and the binding constraint equations that most often set the limits on that interconnector.

Only one constraint equation can be reported as setting the import or export limit for an interconnector at a particular time, so the binding hours will differ from Chapter 3 where two (or more) constraint equations can 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 histograms in this chapter show the flows for the top five (for each direction of flow) binding interconnector limit setting constraint equations. The remaining binding interconnector limit setting constraint equations are summated as "other".

For comparison, the primary axis shows the summated binding hours for the previous year and the secondary axis shows the number of hours the interconnector target was at each flow level (binding or not binding) for the current and past calendar year .

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

5.1. Terranora interconnector (N-Q-MNSP1)

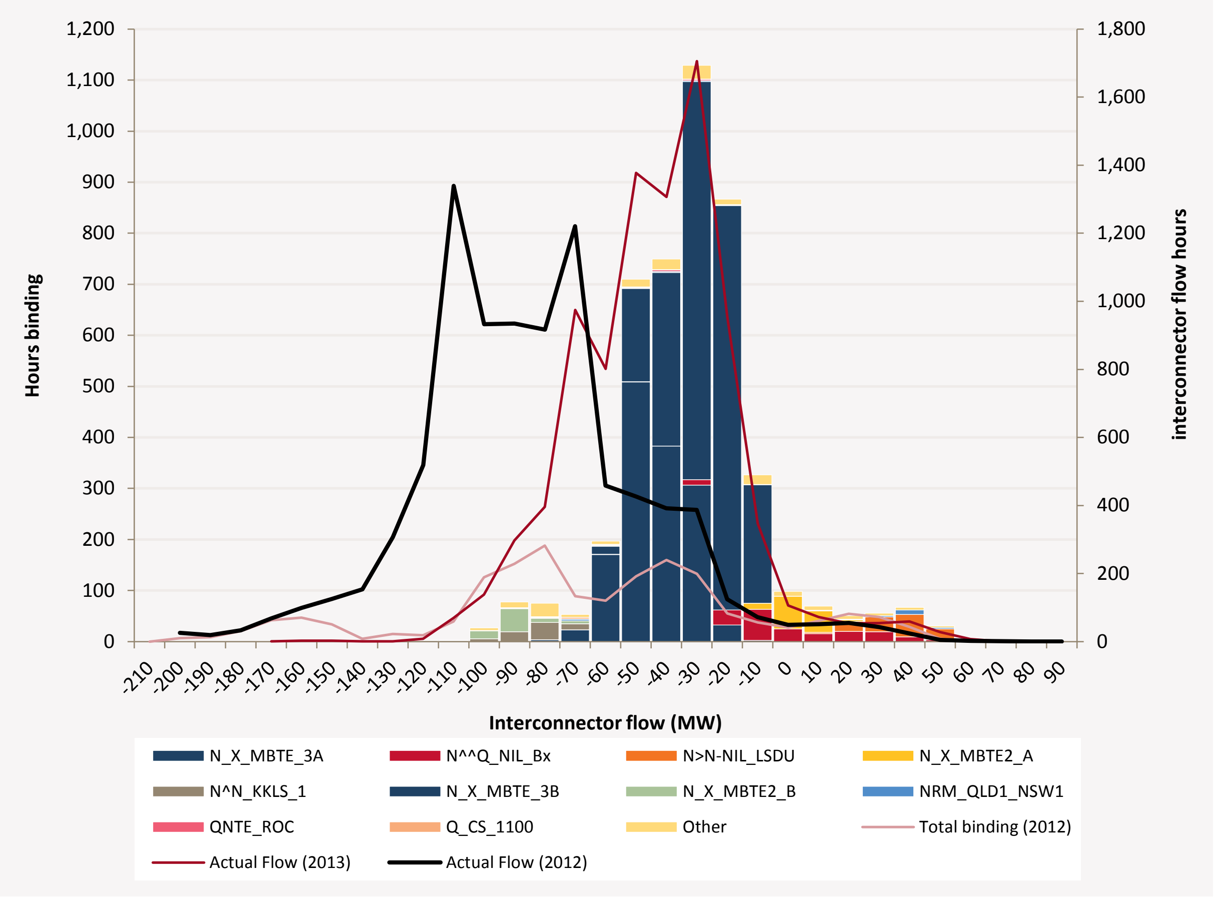
The Terranora interconnector consists of the two 110 kV lines from Terranora in NSW to Mudgeeraba in Queensland. The controllable element is a 180 MW DC link between Terranora and Mullumbimby. The three separate DC cables which make up this link are known as Directlink. The DC cables were commissioned in 2000 and formed the first connection between New South Wales and Queensland.

The majority of flows on this interconnector are towards New South Wales, so both the import and export values are negative (unlike the other NEM interconnectors). It is usually constrained by thermal limits in northern New South Wales (N>N-NIL_LSDU) or rate of change on Directlink (NQTE_ROC, QNTE_ROC).

The Terranora interconnector normally appears along with the Queensland to New South Wales interconnector on the LHS of the stability constraint equations so both interconnectors may be constrained at the same time (normally by N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B and N^Q_NIL_A).

In 2013, most of the time Terranora was restricted was due to the outage of all three Directlink cables (see Figure 5-1).

Figure 5-1 – Binding constraint equation distribution for N-Q-MNSP1



5.2. Queensland to New South Wales Interconnector (NSW1–QLD1)

The Queensland to New South Wales (QNI) interconnector is a 330 kV AC interconnection between Dumaresq in New South Wales and Bulli Creek in Queensland. It was commissioned in 2001 as a double-circuit 330 kV line between Armidale and Braemar and a double-circuit 275 kV line between Braemar and Tarong.

Until 2013 the majority of flows were from Queensland into New South Wales for greater than 500 MW; in 2013 this shifted to only small flows into New South Wales and an increased number of hours for the reverse direction. Due to their close electrical proximity on the New South Wales side, both QNI and Terranora often appear on the LHS of constraint equations.

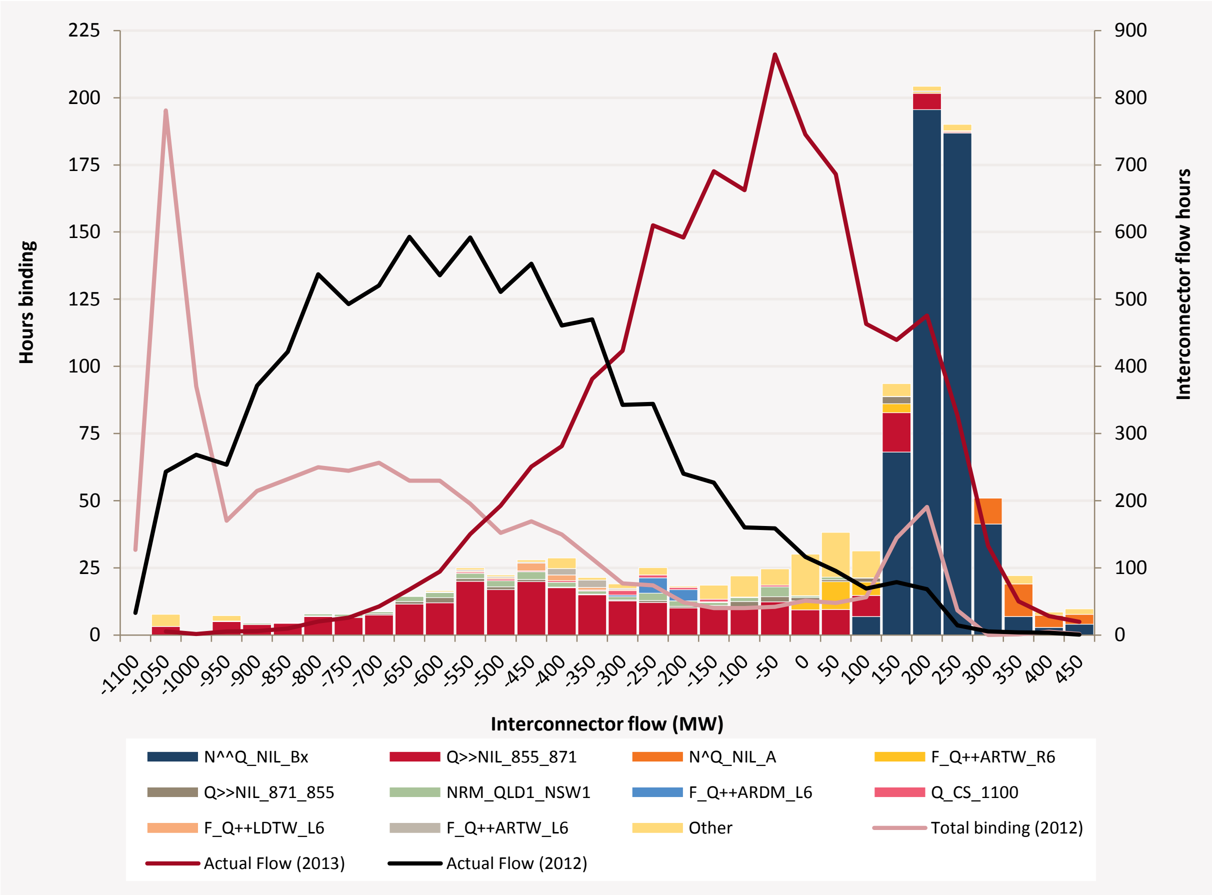
Transfer from New South Wales to Queensland is mainly limited by the system normal constraint equations for the voltage collapse on loss of the largest Queensland unit (N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B) and trip of the Liddell to Muswellbrook (83) 330 kV line (N^Q_NIL_A).

Until November 2013, transfers from New South Wales to Queensland could also be limited by thermal overloads on Calvale to Wurdong (871) 275 kV line or Calvale to Stanwell (855) 275 kV line in Queensland (Q>>NIL_855_871, Q>>NIL_871_855). These thermal limits have been removed with the commissioning of the two Calvale to Stanwell 275 kV lines.

Transfer from Queensland to New South Wales is normally limited by the transient stability limits for fault on a Bulli Creek to Dumaresq line or FCAS requirements for outages of lines between Bulli Creek to Liddell. Prior to July 2013 transfers could be limited by the oscillatory stability limit of 1,078 MW (Q:N_NIL_OSC), this was increased to 1,200 MW on 25 July 2013.

In 2013 the flow was normally from New South Wales to Queensland, the majority of the time flows were between 0 and 250 MW into Queensland (see Figure 5-2). The most constrained flows were into Queensland from New South Wales in particular for flows between 150–250 MW.

Figure 5-2 – Binding constraint equation distribution for NSW1-QLD1



5.3. Basslink (T-V-MNSP1)

Basslink is a DC interconnection between George Town in Tasmania and Loy Yang in Victoria. It 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 between Victoria and Tasmania. Along with the other interconnections to Victoria (VIC1-NSW1, V-SA and Murraylink) Basslink appears in many of the Victorian constraint equations; this can lead to situations where many or all these interconnectors can be limited due to the same network limitation.

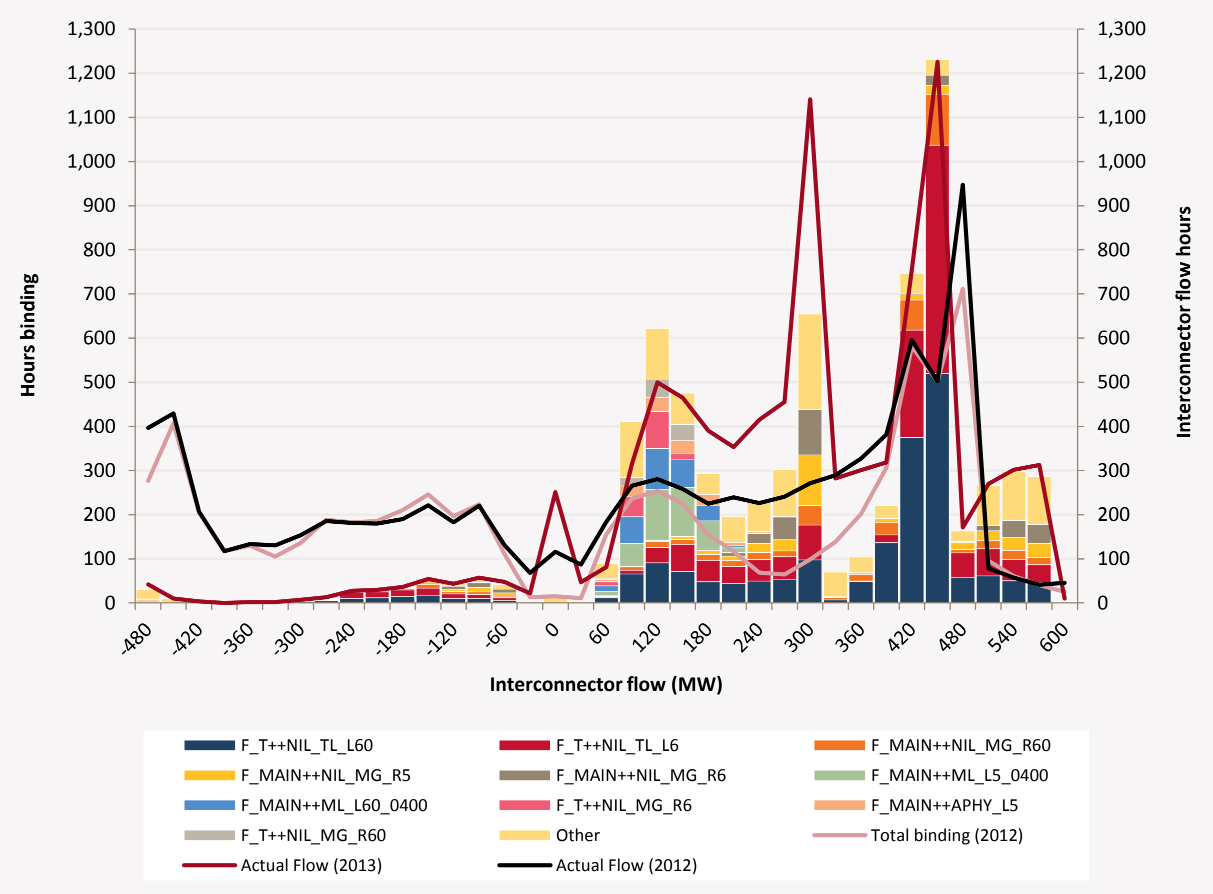
The majority of the limitations on Basslink transfers are due to FCAS constraint equations for both mainland and Tasmanian contingency events.

Tasmania to Victoria transfers are mainly limited by the energy constraint equations for the South Morang F2 transformer overload (V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P) or the transient over-voltage at George Town (T^V_NIL_BL_6).

For Basslink flows from Victoria to Tasmania the energy limitations are due to the transient stability limit for a fault and trip of a Hazelwood to South Morang line (V::N_NILxxx and outage cases).

Similar to previous years, the majority of the flows and binding hours were from Tasmania to Victoria. The 2013 binding hours were higher compared to 2012, particularly between 400–500 MW. Compared to 2012, there were a much larger number of hours for flows at 300 MW (271 hours in 2012 and 1,141 in 2013). This is demonstrated in Figure 5-3.

Figure 5-3 – Binding constraint equation distribution for Basslink



5.4. Victoria to New South Wales (VIC1–NSW1)

The Victoria to New South Wales interconnector combines the 330 kV lines between Murray and Upper Tumut (65), Murray and Lower Tumut (66), Jindera and Wodonga (060), the 220 kV line between Buronga and Red Cliffs (0X1), and the 132 kV bus tie at Guthega (which is normally open).

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. Along with the other interconnections to Victoria (Basslink, V-SA, and Murraylink) VIC1–NSW1 appears in many of the Victorian constraint equations. This can lead to situations where many or all these interconnectors can be limited due to the same network limitation.

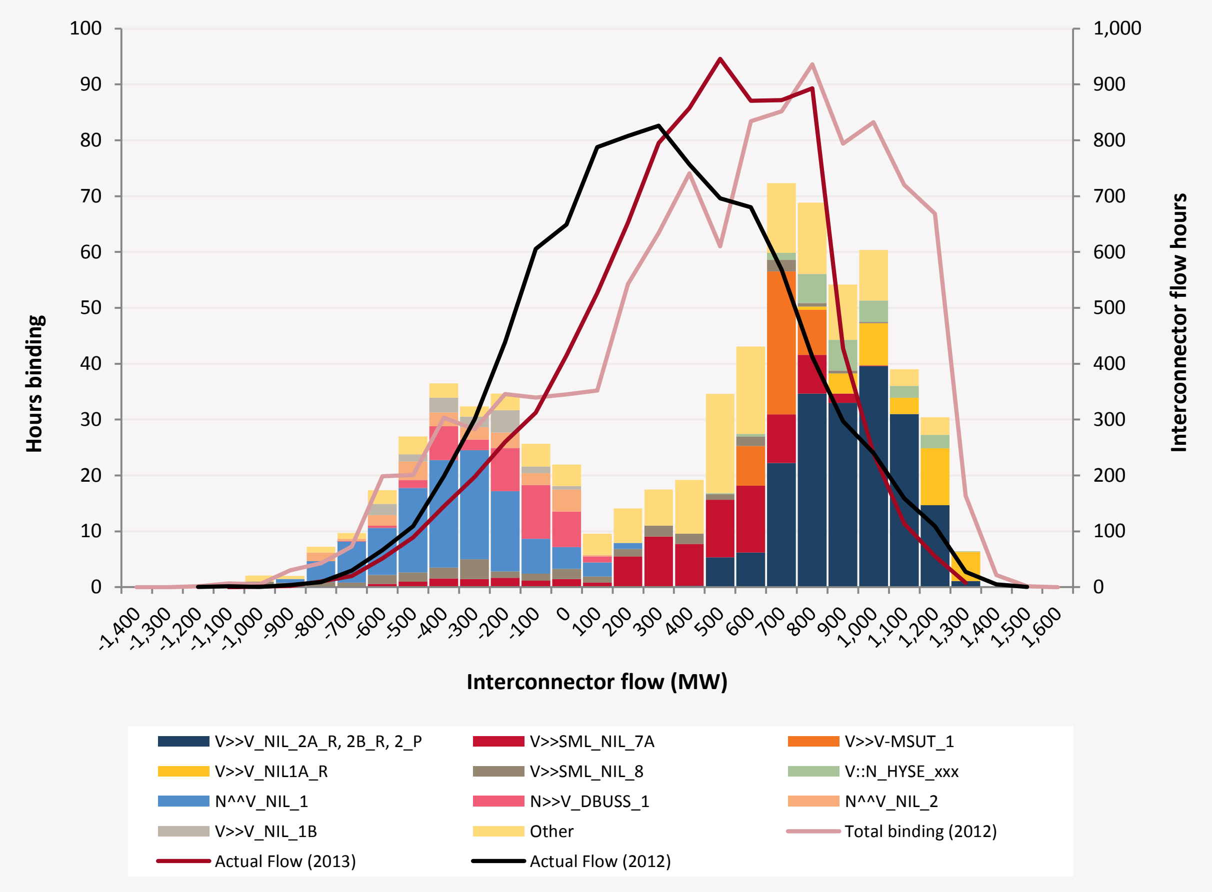
VIC1–NSW1 can bind in either direction for high demand in New South Wales or Victoria. Transfer from Victoria to New South Wales is mainly limited by the thermal overload limits on the South Morang F2 transformer (V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P), the South Morang to Dederang 330 kV line (V>>V_NIL1A_R), the Ballarat to Bendigo 220 kV line (V>>SML_NIL_8), or the Ballarat to Moorabool No.1 220 kV line (V>>SML_NIL_1).

The transient stability limit for a fault and trip of a Hazelwood to South Morang line (V::N_NILxxx and outage cases) can set the limits; however, these constraint equations have rarely bound since the mid-2012.

Transfer from New South Wales to Victoria is mainly limited by voltage collapse for loss of the largest Victorian generator (N^^V_NIL_1), voltage collapse for loss of a Murray to Dederang 330 kV line (N^^V_NIL_2), or the thermal overload limits on the Murray to Dederang 330 kV lines (V>>V_NIL_1B).

The hours at each flow level and binding hours on VIC1–NSW1 were similar in 2012 and 2013. The main difference was high flow levels into New South Wales were constrained for a lower number of hours in 2013 compared to 2012. This is shown in Figure 5-4.

Figure 5-4 – Binding constraint equation distribution for VIC1–NSW1



5.5. Heywood interconnector (V-SA)

The Victoria to South Australia (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 South Australia.

In March 2010 the limit from South Australia to Victoria on Heywood was increased from 300 MW to 460 MW and the combined Heywood and Murraylink limit was increased to 580 MW in January 2011.

Along with the other interconnections to Victoria (VIC1–NSW1, Basslink, and Murraylink) V-SA appears in many of the Victorian constraint equations. This can lead to situations where many or all these interconnectors can be limited due to the same network limitation.

Following a series of increases (from 2011 to 2013) to the voltage collapse limit for loss of the largest South Australian generator (V^^S_NIL_MAXG_xxx), the transfer from Victoria to South Australia is no longer the majority interconnector limit setter (1,026 hours in 2011; 220 in 2012; and down to 209 in 2013).

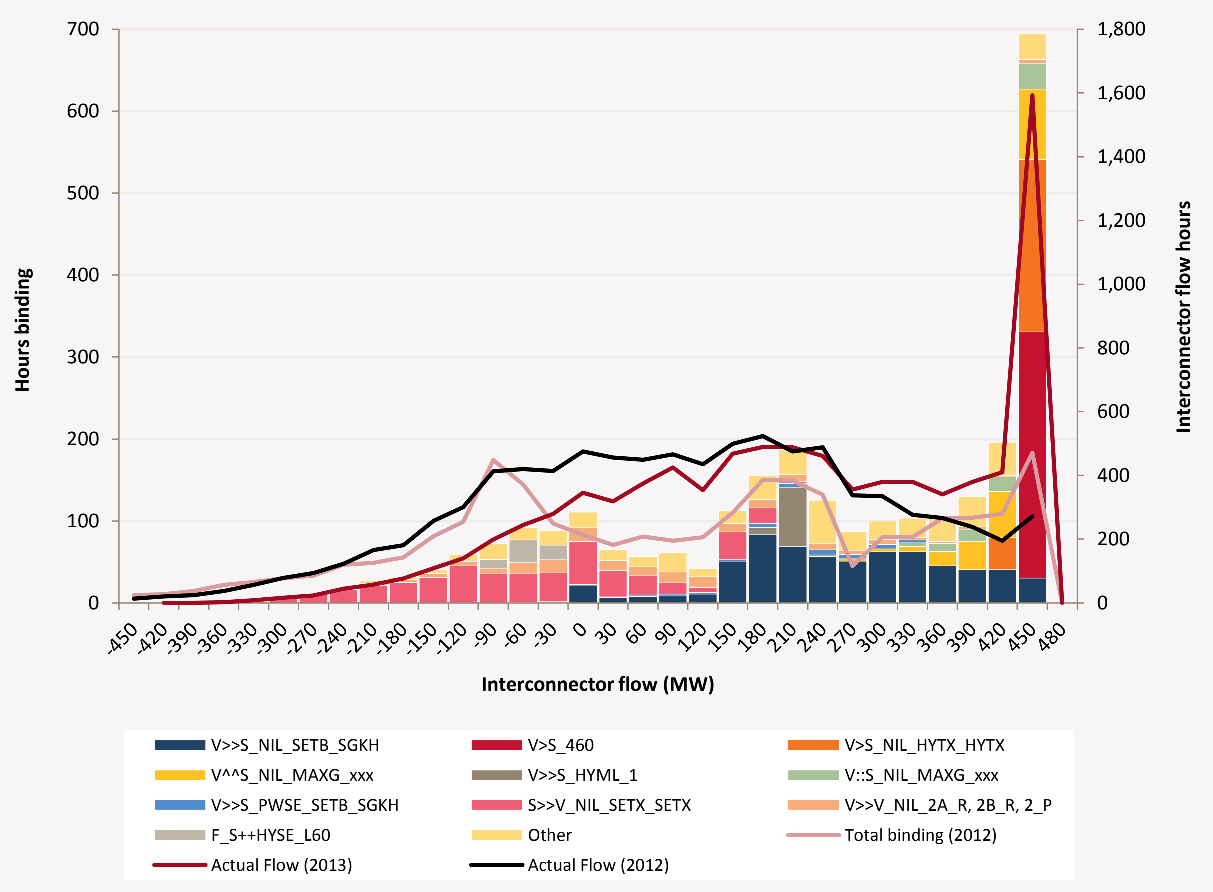
Flows are now most often restricted by thermal overloads on the Snuggery to Keith 132 kV line (V>>S_NIL_SETB_SGKH) and the Heywood 500/275 kV transformers (V>S_460 and V>S_NIL_HYTX_HYTX).

South Australia to Victoria transfers are mainly restricted by the thermal overload limits on the South East substation 275/132 kV transformers (S>>V_NIL_SETX_SETX) and the South Morang F2 transformer (V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P).

In March 2010 the limit from South Australia to Victoria on Heywood was increased from 300 to 460 MW and the combined Heywood and Murraylink limit was increased to 580 MW in January 2011.

The hours at each flow level on V-SA were very similar in 2012 and 2013 with the exception of a more hours for high flows into South Australia (at the 450 MW flow level). There was also a corresponding increase in the binding hours in at the 450 MW flow level compared to the 2012 hours. This is reflected in Figure 5-5.

Figure 5-5 – Binding constraint equation distribution for V-SA



5.6. Murraylink (V-S-MNSP1)

Murraylink is a 220 MW DC link between Red Cliffs in Victoria and Monash in South Australia. It was commissioned in 2002.

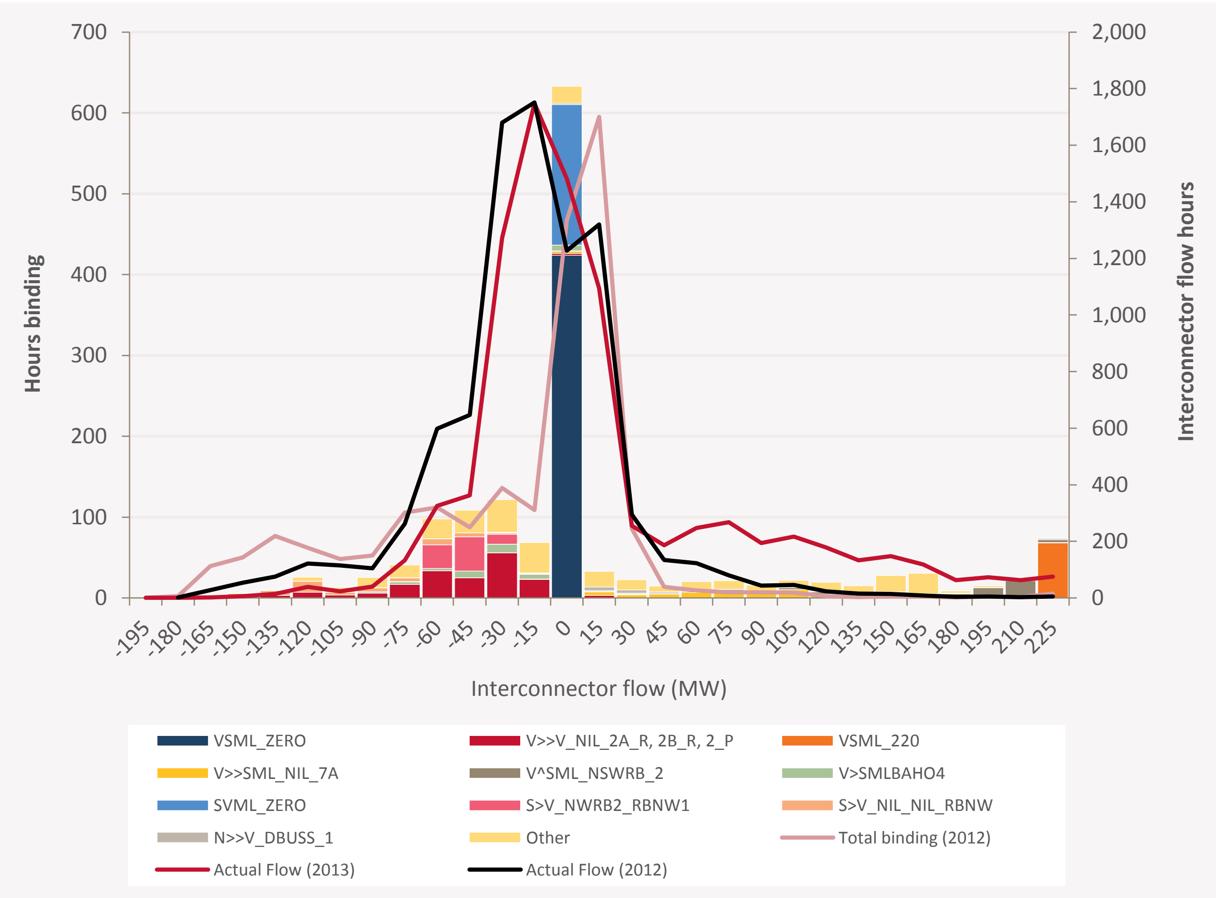
Many of the thermal issues closer to Murraylink are handled by the South Australian or Victorian Murraylink runback schemes. Along with the other interconnections to Victoria (VIC1–NSW1, V–SA and Basslink) Murraylink appears in many of the Victorian constraint equations. This can lead to situations where many or all these interconnectors can be limited due to the same network limitation.

Transfers from Victoria to South Australia on Murraylink are mainly limited by thermal overloads on the South Morang F2 transformer overload (V>>V_NIL_2B_R & V>>V_NIL_2_P), Ballarat North to Buangor 66 kV (V>>SML_NIL_7A), South Morang to Dederang 330 kV (V>>V_NIL1A_R), Ballarat to Bendigo 220 kV line (V>>SML_NIL_8), or voltage collapse limit for loss of the Darlington Point to Buronga (X5) 220 kV line for an outage of the NSW Murraylink runback scheme (V^SML_NSWRB_2[13]).

Murraylink transfers from South Australia to Victoria are limited by thermal overloads on the Robertstown to Monash 132 kV lines (S>V_NIL_NIL_RBNW), the Dederang to Murray 330 kV lines (V>>V_NIL_1B), or the Robertstown transformers (S>>V_NIL_RBTXW_RBTX1).

The number of hours at each flow level on Murraylink was very similar in 2013 and 2012. The main difference was an increase in binding hours at 0 MW (due to a longer outage of Murraylink) in 2013 (27 days in 2013; 14 days in 2012) and an increase at 220 MW into South Australia (upper limit on Murraylink VSML_220). This is shown in Figure 5-6.

Figure 5-6 – Binding constraint equation distribution for Murraylink



13 The NSW Murraylink runback scheme has not yet been commissioned so this constraint equation is currently part of the Victorian system normal constraint set.

6. TRANSMISSION OUTAGES

This chapter details the major transmission outages in 2013 and a comparison of the outage submission and start times for each TNSP.

6.1. Major outages

Table 6-1 shows the duration of 2013 network outages requiring any of the binding constraint equations in the chapter 3, 4, and 5 tables to be invoked. This list excludes outage ramping constraint equations (which start with #) as these are generally not associated with a particular outage. Outage times are calculated from when the constraint sets were invoked.

Table 6-1 – Top 40 outages associated with binding constraint equations

Constraint Set ID	2013 Days (2012 Days)	*Outage* Notes
V-DBUSS_L	233.0 (56.1)	*Dederang DBUSS–Line control scheme*
N-X_MBTE_2	214.9 (60.0)	*Two Directlink cables*
N-X_MBTE_3	158.1 (20.9)	*All three Directlink cables*
F-V-APHY_ONE	87.7 (75.4)	*Heywood to Alcoa Portland 500 kV line*
T-MRWF_100	73.6 (0)	*Discretionary 100 MW upper limit on Musselroe Wind Farm*
S-NWRB2	31.8 (11.6)	*North West Bend to Robertstown No.2 132 kV line*
I-ML_ZERO	27.2 (13.8)	*Limit Murraylink to zero in either direction*
I-HYSE	22.6 (34.1)	*One Heywood to South East 275 kV line*
N-LTUT_64_15M	22.2 (2.5)	*Lower Tumut to Upper Tumut (64) 330 kV line*
V-HYTX	21.6 (28.5)	*One Heywood 500/275 kV (M1 or M2) transformer*
Q-CLTR_8810	18.0 (5.3)	*Calvale to Tarong 275 kV line*
N-EWMB_8505	15.9 (58.3)	*One Ballina to Lennox Head to Ewingsdale to Mullumbimby 66 kV line (8504, 8505, or 8508) or Mullumbimby 132/66 kV transformer*
T-MRWF_120	14.0 (0)	*Discretionary 120 MW upper limit on Musselroe Wind Farm*
I-MSUT	9.0 (4.5)	*Murray to Upper Tumut (65) 330 kV line*
V-BEKG	8.2 (0)	*Bendigo to Kerang 220 kV line*
S-PA_VC_1	6.4 (1.8)	*One Para SVC*
N-EWMB_9G5	6.1 (0)	*One Ballina to Lennox Head to Sufolk Park to Ewingsdale to Mullumbimby 132 kV line*
N-ARTW_86	4.7 (2.0)	*Armidale to Tamworth (86) 330 kV line*
S-BNMT	4.5 (0.9)	*Blanche to Mt Gambier 132 kV line*
S-PWSE	4.4 (11.5)	*Penola West to South East 132 kV line*
N-KKLS_967	3.8 (9.1)	*Koolkhan to Lismore (967) 132 kV line*
V-SMTXF2	2.7 (0.2)	*South Morang 500/330 kV (F2) transformer*
V-HWSM	2.5 (1.7)	*Hazelwood to South Morang 500 kV line*
N-BWMP_ONE	2.5 (0.2)	*Bayswater to Mt. Piper or Bayswater to Wollar or Wollar to Mt. Piper 500 kV line*

Constraint Set ID	2013 Days (2012 Days)	*Outage* Notes
N-CHLS_89	2.2 (1.3)	*Coffs Harbour to Lismore (89) 330 kV line*
V-HYTR	2.1 (1.0)	*Heywood to Tarrone 500 kV line*
V-DDMS	1.5 (9.2)	*One Dederang to Murray (67 or 68) 330 kV line*
NSA-Q_BARCALDN	1.2 (1.1)	*Clermont to Lilyvale (7153) 132 kV line, Network Support Agreement for Barcaldine GT to meet local islanded demand at Clermont and Barcaldine* This NSA constraint set is included as it is only invoked under outage conditions
V-HWCB4	1.2 (1.6)	*Hazelwood to Cranbourne No.4 500 kV line*
V-EPTT_R	1.2 (16.1)	*Eildon to Thomastown 220 kV line*
F-N-ARDM_ONE	1.1 (0.8)	*One Armidale to Dumaresq (8C or 8E) 330 kV line*
I-BCDM_ONE	1.1 (0)	*One Bulli Creek to Dumaresq 330 kV line*
F-I-BCDM_ONE	1.1 (0)	*One Bulli Creek to Dumaresq 330 kV line - FCAS Requirements*
N-ARTW_MPP_N-2	1.0 (0)	*Armidale to Tamworth 330 kV line*
V-HWRO3	1.0 (2.1)	*Hazelwood to Rowville No.3 500 kV line*
S-LB3_0	0.9 (0.8)	*Discretionary upper limit for Lake Bonney 3 generation of 0 MW*
V-HYMO	0.9 (6.5)	*Heywood to Mortlake No.2 500 kV line*
S-X_MTSE+PAVC_1	0.7 (0)	*Mt. Gambier to South East 132 kV line and Para SVC 1 or Para SVC 2*
S-SESG	0.6 (0)	*South East to Snuggery 132 kV line*
S-PA_WEST_BUS_R	0.5 (0)	*Para 275 kV West Bus Right Section*

6.2. Trends for submit times

Figure 6-1 shows the trends relating to the length of time between when a network outage is submitted to AEMO's network outage schedule (NOS) and the actual outage start time. The times are divided into four categories:

- Unplanned: The outage was submitted on or after the start time for the outage.
- Short notice: The outage was submitted within four days of the start time.
- ≤ 30 days: The outage was submitted within 30 days of the start time.
- 30 days: The outage was submitted more than 30 days before the start time.

Outages that were submitted previously and then rescheduled for a new time are recorded as new outages in the NOS. Outages for multiple items of related plant that are submitted in a single entry are only counted as a single outage.

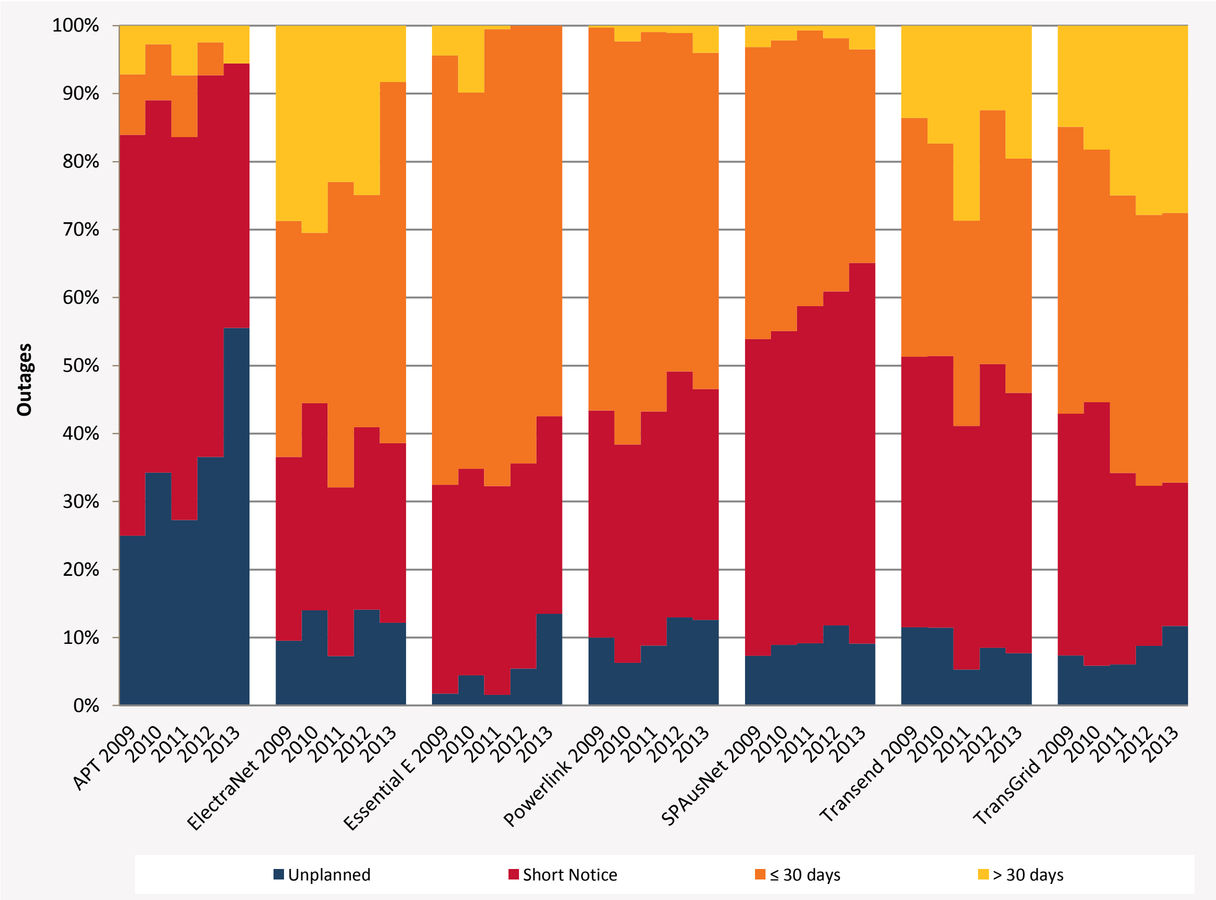
APT, Essential Energy, TransGrid, and Transend submit their 13-month outage plans via NOS. Powerlink, ElectraNet, and SP AusNet submit theirs via a spreadsheet and are not included in these statistics.

AEMO has observed the following trends:

- Since 2009, over 80% of APT outages are unplanned or short notice. (APT operate Murraylink and Directlink DC cables.) This has increased to over 90% in the past two years.
- For other NSPs less than 10% of outages are forced and majority of the outages are either short notice or within 30 days.

- Compared to other TNSPs TransGrid and Transend have a higher percentage of their outages submitted greater than 30 days before the start time.
- Very few outages are submitted by Essential Energy, Powerlink, SPAusNet, or APT for greater than 30 days out.
- The percentage of ElectraNet's outages submitted more than 30 days from the start time has decreased.

Figure 6-1 – Outage submit times versus start time



MEASURES AND ABBREVIATIONS

6.3. Units of measure

Unit of measure	Expanded name
MW	A watt (W) is a measure of power and is defined as one joule per second and it measures the rate of energy conversion or transfer. A Megawatt is one million watts.

6.4. Abbreviations

Abbreviation	Expanded name
CVP	Constraint violation penalty factor
DNSP	Distribution network service provider
EMS	Energy management system
FCAS	Frequency control ancillary service
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.
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.
TNSP	Transmission network service provider

GLOSSARY

Term	Definition
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.
Mainland	The NEM regions: Queensland, New South Wales, Victoria and South Australia
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