NEM CONSTRAINT REPORT 2014

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. It provides electricity market professionals with an overview of the trends that affect the amount and value of congestion in the NEM.

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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 changes in congestion patterns, comparing last year's outcome with those of the previous five years.

This report details constraint equation performance, and issues related to transmission congestion for the 2014 calendar year. It includes:

- The drivers for constraint equation changes
- 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. 2014 had the largest number of transmission and generator changes since 2009. This led to the largest number of constraint equation changes since 2010, with a total of 8,121 (see chapter 2).
2. The market impact due to binding constraints was lower than in 2013, but was still the third highest since the data became available in 2009 (see chapter 4).

Year	Constraint changes	Market impact ($/MW/DI)
2009	8,594	$39 million
2010	6,250	$28.3 million
2011	4,776	$21.3 million
2012	4,130	$30.3 million
2013	5,817	$37.5 million
2014	8,121	$30.5 million

3. In 2014, flows on the Queensland to New South Wales interconnector were mainly constrained from Queensland to New South Wales – a reversal on the direction in 2013 (see section 5.2).

   Basslink's flow was constrained for a much larger number of hours in 2014 compared to 2013: 563 hours versus 30 (see section 5.3).

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1. CURRENT CONSTRAINT STATISTICS

At 31 December 2014, the total number of constraint sets, equations, and functions available in AEMO's electricity market management system (MMS) were:

- 3,424 constraint sets: up from 3410 in the previous year
- 10,303 constraint equations: up by 368 from the previous year's 9,935
- 359 constraint functions: down from 366 in the previous year.

Excluded from these totals are any constraint sets, equations, or functions that were archived before December 2014, and any that were created by the outage ramping process.[1] Outage ramping constraint sets and equations are generated for single use by AEMO's control room staff, so these are excluded from the above results.

Figures 1 and 2 that follow, exclude outage ramping and constraint automation-built constraint equations, to prevent the results being swamped. Also excluded are any constraint equations that are not in a constraint set (and therefore cannot be active in the NEMDE).

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

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

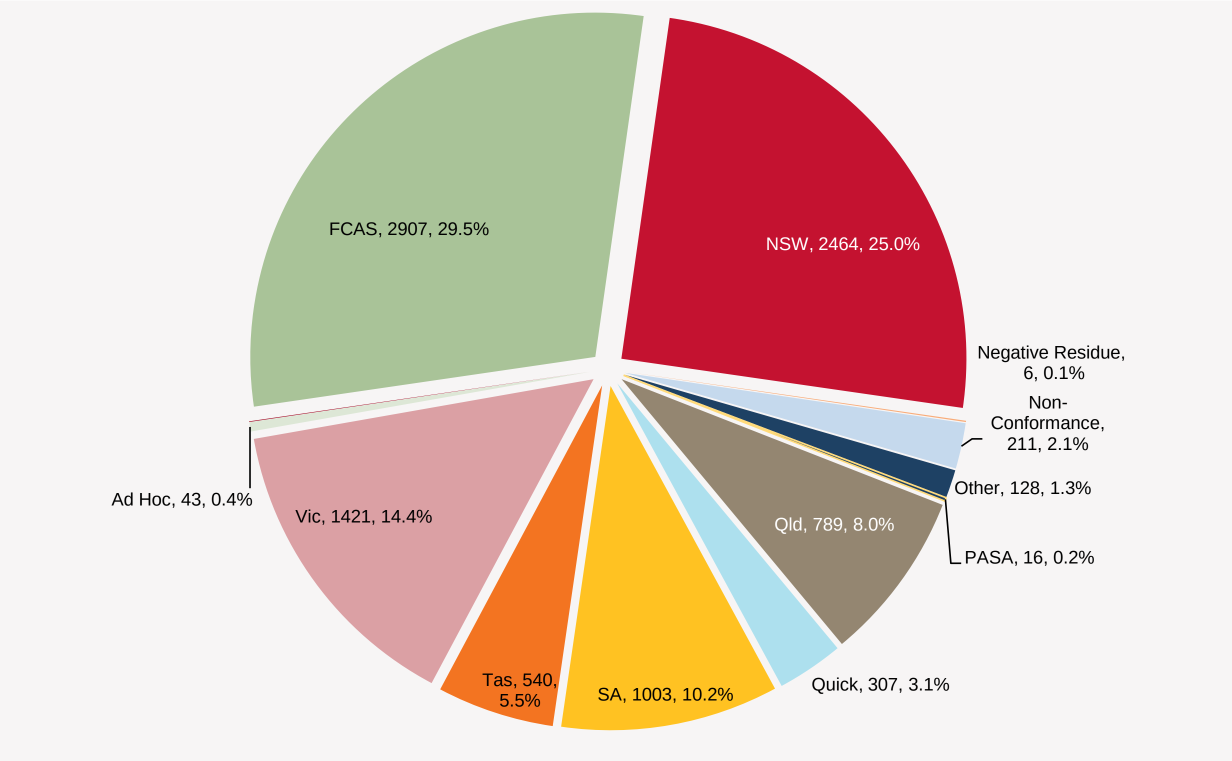


Figure 1 shows that most constraint equations are for FCAS, New South Wales, and then Victoria.

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

Figure 2 below shows that the main types of constraint equations are for thermal overloads (31.2%) and FCAS (20.2%).

Quick constraint equations (in Figure 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.

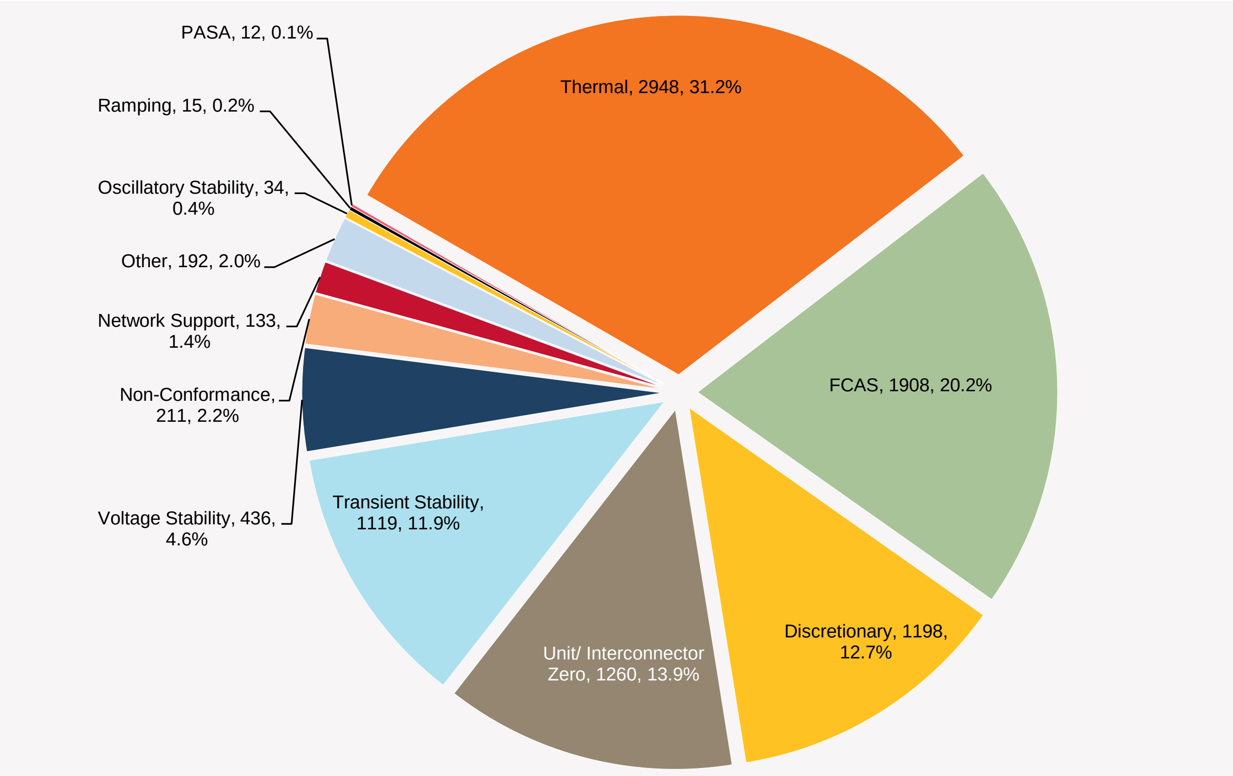
Ad hoc constraint equations are also created by AEMO's control room staff. These are mainly created for a large number of LHS terms. The software that creates quick constraints now handles more complex LHSs, so ad hoc constraint equations are rarely built.

In Figure 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".

There were only a few changes to the breakup of the constraint equations in 2014, compared to the previous year, specifically:

- NSW increased from 2,043 to 2,462.
- Tasmania decreased from 672 to 540.
- South Australia decreased from 1,146 to 1,003.
- Total thermal constraint equations increased from 2,910 to 2,948. This is attributed to the increase in NSW constraint equations.

Figure 2 Constraint equations by limit type



2. CONSTRAINT EQUATION CHANGES

One of the main drivers for constraint equation changes is power system changes, i.e., plant additions or removals (either generation or transmission).

The tables in this chapter list transmission system and generator changes separately. Only changes on the main high voltage (greater than 110 kV) transmission system are listed, as these normally cause changes to the constraint equations.

In 2014, the number of generator and transmission changes was the highest since 2009. This led to a relative large number of constraint equation changes this year.

2.1 Generators added or removed in 2014

The following list includes all scheduled and semi-scheduled generators either added to the power system in 2014, or removed. It also lists non-scheduled plants large enough to have caused constraint equation changes.

In 2014, only NSW had generator changes, with three new wind farms registering and de-registering of four existing generators. The number of new registrations was the second lowest since 2009. (There were 13 in 2009, four in 2010, five in 2011, two in 2012, and five in 2013).

Commissioning the new NSW generators had a large impact. There were 5272 constraint equation changes in NSW – the highest number ever.

In Victoria, the establishment of Mt Mercer generator (registered in 2013) caused changes on constraint equations.

Table 1 Generator changes in 2014

Generator	Registration Date	Region	Notes
Munmorah Unit 4	29 May 2014	NSW	Deregistered Generator
Munmorah Unit 3	29 May 2014	NSW	Deregistered Generator
Wallerawang Unit 7	20 June 2014	NSW	Deregistered Generator
Boco Rock WF	29 August 2014	NSW	New Generator
Taralga Wind Farm	11 December 2014	NSW	New Generator
Nyngan Solar Farm	16 December 2014	NSW	New Generator
Wallerawang Unit 8	30 December 2014	NSW	Deregistered Generator

2.2 Transmission changes in 2014

In 2014, the number of transmission changes increased to 30 (from 28 in 2013, 19 in 2012, 21 in 2011, 17 in 2010, and 21 in 2009). Reconfiguration of the 110 kV network in Tasmania’s Derwent Valley, and the commissioning of three reactors at Murray and Yass caused the largest impacts on constraint equations.

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

Table 2 Transmission changes in 2014

Generator	Registration Date	Region	Notes
Sydney East No.4 330/132 KV Transformer	5 January 2014	NSW	
Yass #1 330 kV reactor commissioned	4 February 2014	NSW	
Meadowbank to Tungatinah 110 kV line	7 February 2014	Tas	Part of larger project - the rearrangement of Tarraleah and Tungatinah substations
Yass #2 330 kV reactor	15 February 2014	NSW	
Holroyd to Sydney West (1C) 330 kV line	8 March 2014	NSW	Includes commissioning of new Holroyd substation, No. 2 transformer and "B" bus
Western Downs to Orana (8889) 275 kV transmission line and Orana 275 kV substation	13 March 2014	Qld	
Holroyd to Sydney West (1F) 330 kV line	16 March 2014	NSW	
Murray No.3 330 kV reactor	17 March 2014	NSW	
Cultana to Yadnarie 132 kV line	19 March 2014	SA	
Murray No.1 330 kV reactor	22 March 2014	NSW	
Murray No.2 330 kV reactor	30 March 2014	Vic	
Cultana to Whyalla No.1 132 kV line	4 April 2014	SA	
Collinsville North to Strathmore (7127) 132 kV line	9 April 2014	Qld	Existing 7127 cut into new Collinsville North substation which replaces the Collinsville substation
275 kV Reactor at Chalumbin	10 April 2014	Qld	
New Norfolk to Tungatinah No.1 110 kV line	2 May 2014	Tas	New Norfolk to Tarraleah No.1 moved to Tungatinah. Part of larger project - the rearrangement of Tarraleah and Tungatinah substations.
New Norfolk to Tungatinah No.1 110 kV line commissioned	2 May 2014	Tas	The line was commissioned replacing the New Norfolk to Tarraleah No.1 110 kV line.
Creek Road to Risdon No.1 110 kV line	23 May 2014	Tas	
Orana to APLNG Orana (8894 and 8895) 275 kV lines	4 June 2014	Qld	
Columboola 275 kV substation	18 June 2014	Qld	
Decommissioning of Collinsville to Collinsville North (7411) 132 kV line	18 June 2014	Qld	
Canberra C4 120 Mvar capacitor bank	7 August 2014	NSW	
Gladstone North to Wiggins Island (7414) 132 kV line	7 August 2014	Qld	
New Norfolk to Tungatinah No.2 110 kV line commissioned	12 August 2014	Tas	This line was commissioned replacing the New Norfolk to Tarraleah No.2 110 kV line.
Columboola – Wandoan South 8892 275 kV transmission line	11 September 2014	Qld	Commissioning
New Norfolk to Tungatinah No.3 110 kV line commissioned	16 September 2014	Tas	This line was commissioned isolating Meadowbank power station as part of Meadowbank redevelopment project.
Yass C1 132 kV 80 MVar Capacitor Bank	23 September 2014	NSW	
Collinsville North to Mackay Tee Proserpine (7125) 132 kV transmission line	25 September 2014	Qld	
Wandoan South (H76) No.2 275/132 kV Transformer commissioned	26 September 2014	Qld	
Collinsville North to Mackay Tee Proserpine (7126) 132 kV line commissioned	10 October 2014	Qld	
Blackwall to Greenbank (8819) 275 kV transmission line re-commissioned as Blackwall to Goodna (8819) 275 kV transmission line	6 November 2014	Qld	

2.3 Comparisons of constraint equation changes

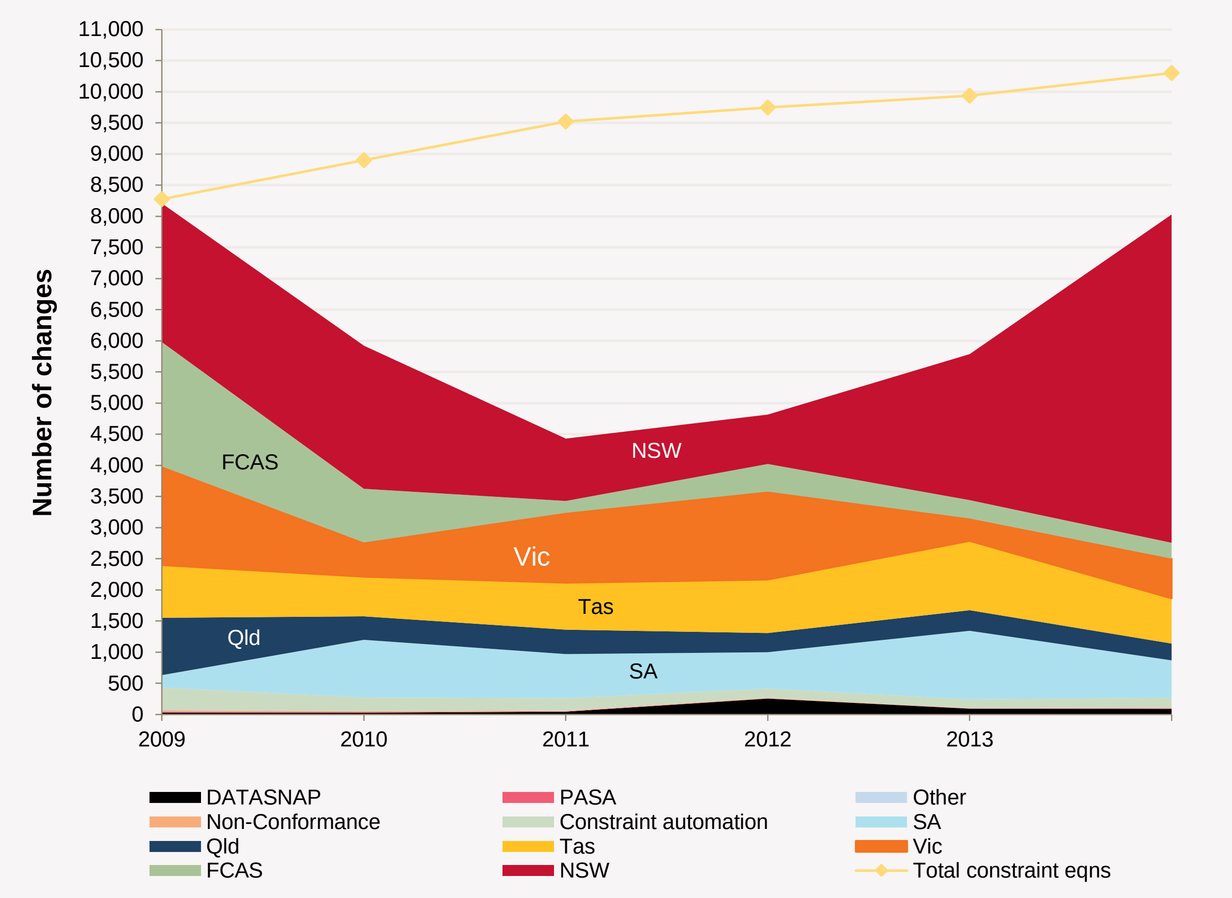
Figure 3 compares annual constraint equation changes by region. It also includes a comparison of each calendar year's total number of constraint equations in the NEM.

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, while others are more complex and require several days of work.

These results measure when the constraints were updated, not when they became active. For example, 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[2], which required 8,833 constraint equation updates. Nor does it include the changes due to the real time constraint automation.[3]

Figure 3 Constraint equation changes per calendar year, 2009 to 2014



As shown in Figure 3, the total number of constraint changes in 2014 (8,121) was the highest since 2009. In 2014, New South Wales dominated with 65% of the changes, followed by Tasmania, Victoria and South Australia with 9%, 8% and 7% of changes respectively.

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

[3] 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: 17 Feb 2014.

The number of changes in 2014 was above the 10-year average of 5,777, and most similar to the number in 2009 of 8,275. The volume of constraint equation changes in the past five years was due to:

- 2009: changes to Tasmanian frequency operating standards
- 2009 and 2010: multiple stages of the New South Wales western 500 kV project.
- 2013: changes to operating margins across multiple regions; the new Gullen Range Wind Farm in New South Wales; and Musselroe Wind Farm in Tasmania requiring changes in those regions.
- 2014: de-registering Wallerawang and Munmorah; the new wind farms at Boco Rock and Taralga; and solar farm at Nyngan resulting in a high number of changes to New South Wales constraint equations.

The limited number of power system or market changes impacting FCAS explains the low number of FCAS constraint equation changes in 2014.

3. BINDING

This chapter examines the top 20 binding constraint equations in 2014. A constraint equation is binding when the power system flows that it manages, have reached their applicable thermal or stability limits, or the constraint equation is setting a frequency control ancillary service (FCAS) requirement. When a constraint equation is binding, NEMDE has changed the generator and interconnector targets in order to satisfy the constraint equation, compared to an unconstrained system. The market impact of this is discussed in Chapter 4.

At any time, there is at least one constraint equation setting the requirement for each of the eight FCAS services. 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 and Table 4 below).

In the tables, system normal constraint equations are listed in bold, and the number of binding hours for 2013 (if any) is indicated in brackets below the 2014 hours. The tables also 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[4] or via the MMS data model.[5]

Some constraint equations only bind at certain times of the year (such as winter or summer). Figure 4 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 and Table 4 below are system normal constraint equations and not those for outage cases.

3.1 Network constraint equations

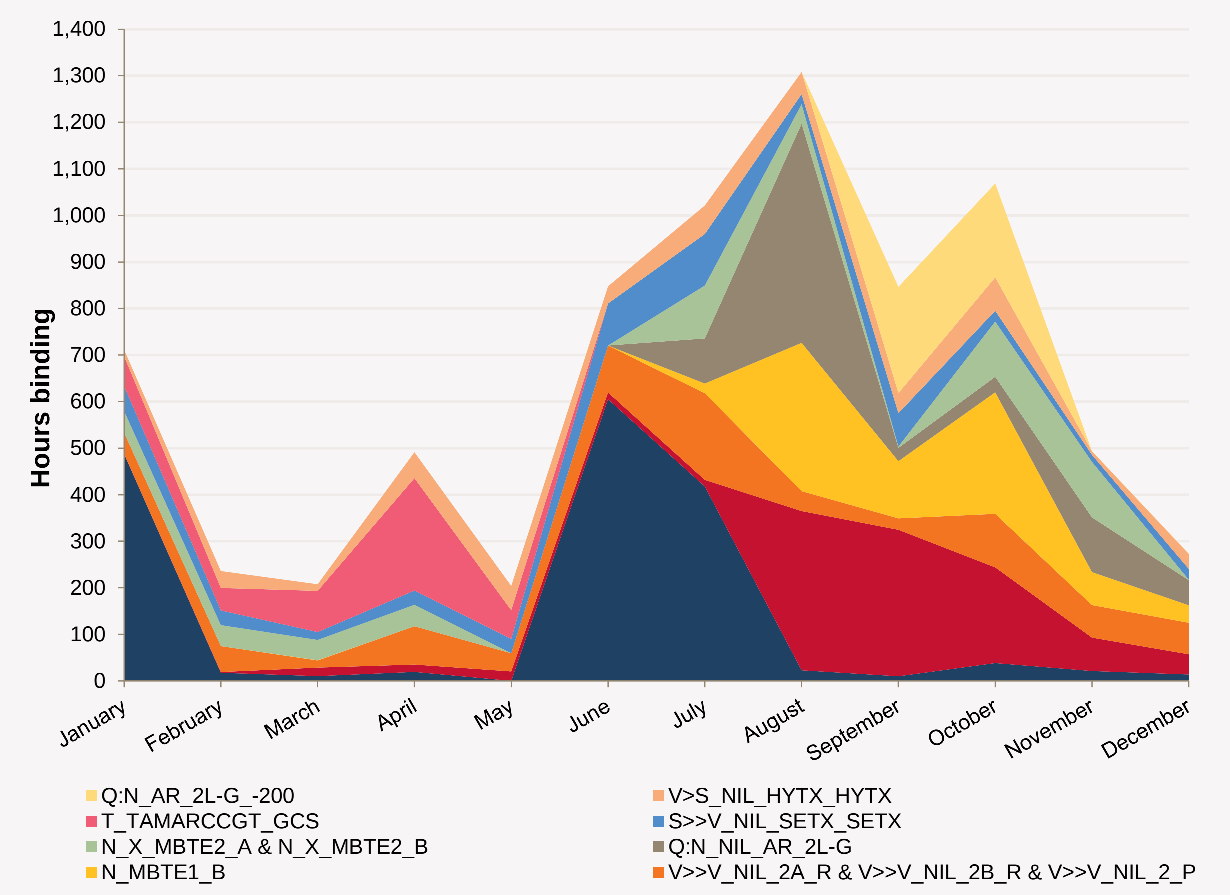
Table 3 Top 20 binding network constraint equations

Constraint Equation ID (System Normal Bold)	2014 Hours (2013 Hours)	*Description* Notes
N_X_MBTE_3A and N_X_MBTE_3B	1,662 (3,773)	*Out = all three Directlink cables* All three Directlink cables was out for 70.3 days in 2014 compared to 158.1 days in 2013. See Table 6.
Q>NIL_BI_FB	1,063 (493)	*Out = Nil, avoid overloading on Boyne Island feeder bushing on Calliope River to Boyne Island 132 kV lines, for the contingent loss of a single Calliope River to Boyne Island 132 kV line*
V>>V_NIL_2A_R and V>>V_NIL_2B_R and V>>V_NIL_2_P	844 (202)	*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.
N_MBTE1_B	834 (1)	*Out = one Directlink cable, Queensland to NSW limit* One Directlink cable was out for 365.0 days in 2014 compared to zero days in 2013. See Table 6.

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

Constraint Equation ID (System Normal Bold)	2014 Hours (2013 Hours)	*Description* Notes
Q:N_NIL_AR_2L-G	800 (0)	*Out = Nil, avoid transient instability for a 2 line to Ground fault at Armidale*
N_X_MBTE2_A and N_X_MBTE2_B	580 (196)	*Out = two Directlink cables* Two Directlink cables was out for 169.8 days in 2014 compared to 214.9 days in 2013. See Table 6.
S>>V_NIL_SETX_SETX	517 (456)	*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.
T_TAMARCCGT_GCS	504 (358)	*Limit output of Tamar Valley Power Station based on load available for shedding by Tamar Valley 220 kV generation control scheme (GCS)*
V>S_NIL_HYTX_HYTX	474 (992)	*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.
Q:N_AR_2L-G_-200	430 (0)	*Out = Bulli Creek CBs (8L2 and 99012) or (8M2 and 99022)* The Bulli Creek CBs (8L2 and 99012) or (8M2 and 99022) was out for 130.9 days in 2014 compared to 0 days in 2013. See Table 6.
V_T_NIL_FCSPS	335 (1)	*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.
V::N_NIL_xxx	317 (11)	*Out = Nil, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* There are twelve constraint equations that make up the transient stability export limit from Victoria and all the binding results have been combined.
V>>S_NIL_SETB_SGKH	288 (652)	*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.
S>V_NIL_NIL_RBNW	242 (52)	*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.
N^^V_NIL_1	210 (104)	*Out = Nil, avoid voltage collapse for loss of the largest Victorian generating unit*
S>>NIL_SETB_KHTB1	197 (27)	*Out = Nil, avoid overloading Keith - Tailem Bend #1 132kV on trip of South East - Tailem Bend 275kV line*
V^^S_NIL_MAXG_xxx	179 (209)	*Out = Nil, Victoria to SA long term voltage stability limit for loss of the largest credible generation contingency in SA, South East capacitor bank on / off* There are two constraint equations that make up the voltage stability export limit from Victoria to South Australia and all the binding results have been combined.
SVML_ZERO	170 (175)	*Upper transfer limit of 0 MW on SA to VIC on Murraylink* This limit is used when Murraylink is out of service. This was the case for 10.0 days in 2014 compared to 27.2 days in 2013. See Table 6.
Q>NIL_TR_TX1_4	165 (121)	*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)*
V_T_NIL_BL1	164 (9)	*Out=Nil, Basslink no go zone limits Victoria to Tasmania*

Figure 4 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 4 Top 20 binding FCAS constraint equations

Constraint Equation ID (System Normal Bold)	2014 Hours (2013 Hours)	*Description* Notes
F_I+NIL_MG_R5	7,678 (7,086)	*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	6,734 (6,285)	*NEM raise 6 second requirement for a NEM generation event*
F_I+NIL_MG_R60	6,666 (6,256)	*NEM raise 60 second requirement for a NEM generation event*
F_I+NIL_APD_TL_L5	5,723 (0)	*NEM Lower 5 min Service Requirement for the loss of APD potlines*
F_I+NIL_DYN_LREG	4,222 (5,354)	*NEM lower regulation requirement*
F_I+NIL_APD_TL_L60	3,890 (0)	*NEM Lower 60 sec Service Requirement for the loss of APD potlines*
F_I+ML_L6_0400	3,125 (3,416)	*NEM lower 6 second requirement for a NEM load event*
F_T++NIL_TL_L6	2,402 (4,629)	*Tasmania lower 6 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*

Constraint Equation ID (System Normal Bold)	2014 Hours (2013 Hours)	*Description* Notes
F_T++NIL_TL_L60	2,333 (5,130)	*Tasmania lower 60 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS*
F_I+NIL_DYN_RREG	2,274 (1,880)	*NEM raise regulation requirement*
F_MAIN++APD_TL_L5	1,979 (0)	*Mainland lower 5 min Service Requirement for the loss of APD potlines, Basslink able to transfer FCAS*
F_MAIN++APD_TL_L60	1,855 (0)	*Mainland lower 60 sec Service Requirement for the loss of APD potlines, Basslink able to transfer FCAS*
F_MAIN++NIL_MG_R60	1,840 (2,424)	*Mainland raise 60 second requirement for a mainland generation event, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R6	1,583 (1,548)	*Mainland raise 6 second requirement for a mainland generation event, Basslink able transfer FCAS*
F_I+TL_L5_0500	1,275 (13)	*NEM lower 5 min Service Requirement for a NEM network event*
F_T+NIL_BL_R60_1 and F_T++NIL_BL_R60_x	1,104 (205)	*Tasmania raise 60 second requirement for loss of Basslink, FCSPS available* *See note for F_T+NIL_BL_R6_1 and F_T++NIL_BL_R6_x*
F_MAIN++ML_L6_0400	1,081 (535)	*Mainland lower 6 second requirement for a mainland load event, Basslink able transfer FCAS*
F_MAIN++NIL_MG_R5	1,044 (1,466)	*Mainland raise 5 minute requirement for a mainland generation event, Basslink able transfer FCAS*
F_T+NIL_BL_R6_1 and F_T++NIL_BL_R6_x	1,038 (292)	*Tasmania raise 6 second requirement for loss of Basslink, FCSPS available* In November 2011 the 4 constraint equations were replaced with 2 constraint equations due to advice that the loss of link time on Basslink was changed to 400ms. The binding results from all the constraint equations have been combined.
F_T++RREG_0050	1,034 (319)	*Tasmania raise regulation requirement greater than 50 MW, Basslink able transfer FCAS*

3.3 Binding Trends

Figure 5, Figure 6 and Figure 7 show the binding constraint equations for the past six years, categorised by region, limit type, and whether the system is normal or in outage. Note that Figure 5 and Figure 7 excludes binding FCAS hours (whether system normal or outage) while Figure 6 excludes the system normal FCAS binding hours. This is because FCAS constraints bind frequently and would dominate the graphs (all figures). Also, specific to Figure 5, in most cases FCAS can not be attributed to a single region.

The three graphs below indicate the following trends:

- Total binding hours in 2014 were similar to the 2009 total, but lower than the peak in 2013. New South Wales had the highest number of binding hours and Tasmania the lowest.
- New South Wales binding hours in 2014 remained very high (3586 hours) but less than the 2013 total (5,095 hours). The high 2013 number was due to the increase in binding hours for the New South Wales to Queensland voltage stability and Directlink constraint equations. The decrease in 2014 can be attributed to an increased availability of the Directlink cables.
- The Queensland binding hours indicate peaks in 2010 and 2014. The 2010 peak was due to the transient stability constraint for Queensland to New South Wales flows and the Calvale to Wurdong thermal overload constraint. The 2014 peak was due to the constraint equation for the thermal overload on Boyne Island feeder bushing.
- The Tasmanian binding hours peak in 2013 is due to the commissioning of the Musselroe wind farm.
- Voltage stability constraint equations in 2011 had a peak of 2,091 hours of binding. They are binding at lower levels compared to 2013.

- Thermal overload constraint equations bound for 5,514 hours in 2014 – down from the 2013 peak of 6,633 hours but still the second highest since 2009.
- Transient stability binding constraint equations had an all-time low in 2013 of 171 hours, largely because of the reduced binding hours of the updated Victoria to New South Wales transient stability constraint equations. In 2014, the binding hours were back to historically normal levels (1,776 hours), due to the Queensland to New South Wales transient stability limit for fault at Armidale – both for system normal (800 hours) and outages of the Bulli Creek circuit breakers (430 hours).
- System normal binding hours in 2013 and 2014 increased to 7,521 and 8,116 hours, respectively. This is up from the all-time low in 2012 (5,333 hours) that was achieved after a declining trend since 2008.
- The outage binding hours also showed a decreasing trend from 2008 to 2012, but rose again in 2013 with a peak of 8,708 hours, and settled back down again in 2014 with 5,353 hours.

Figure 5 Binding constraint equations by region

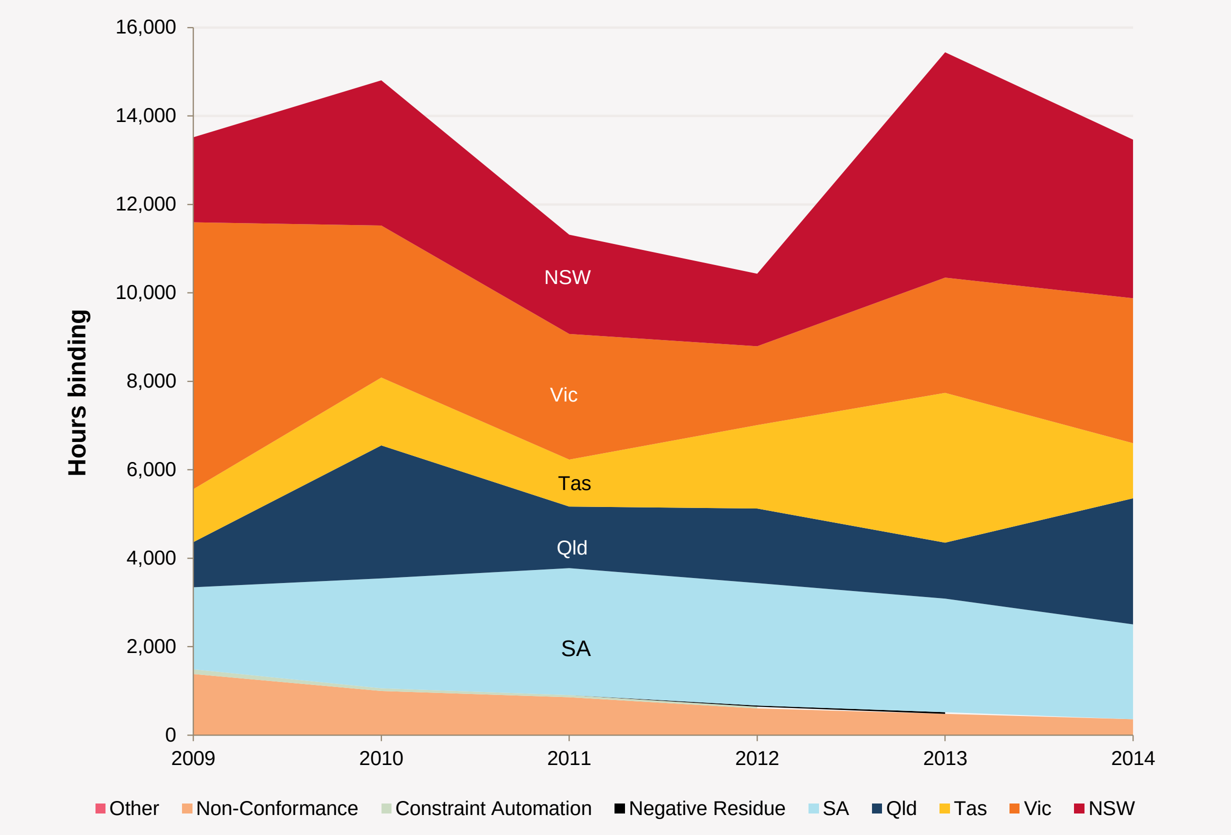


Figure 6 Binding constraint equations by limit type

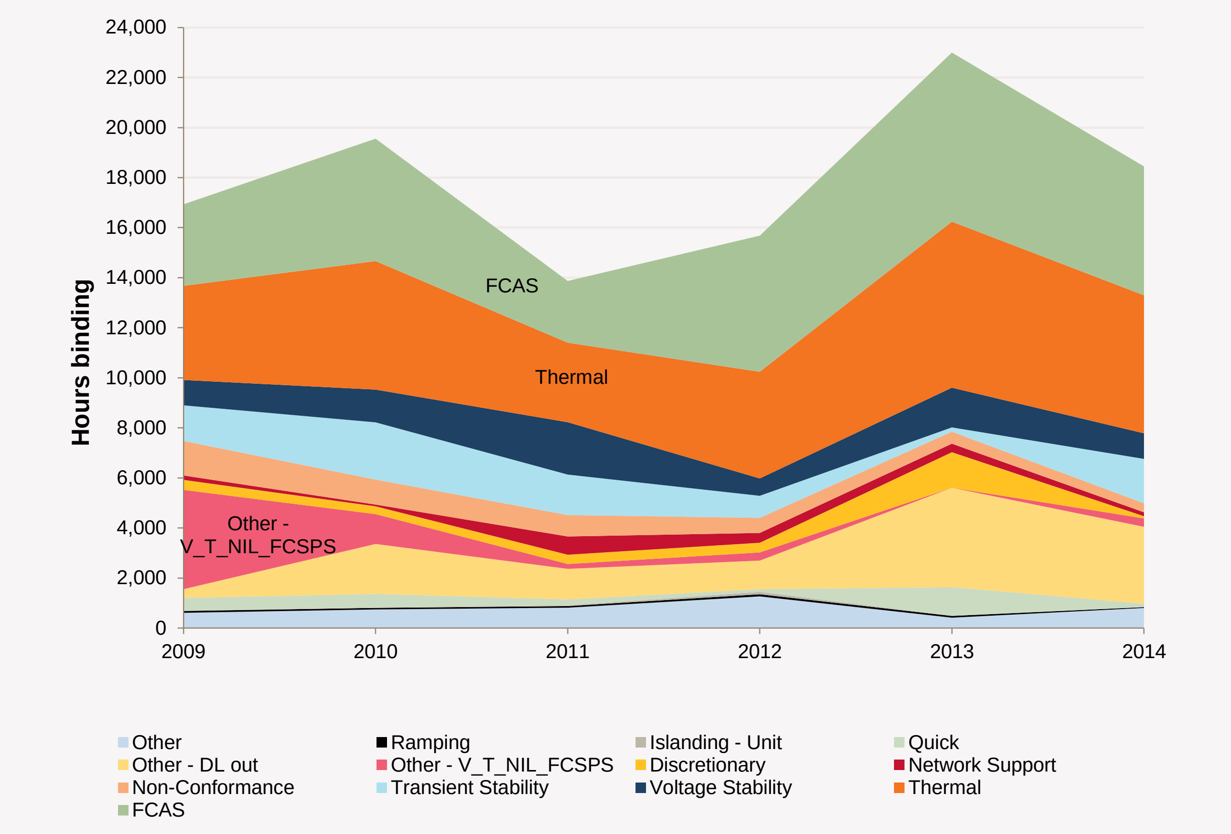
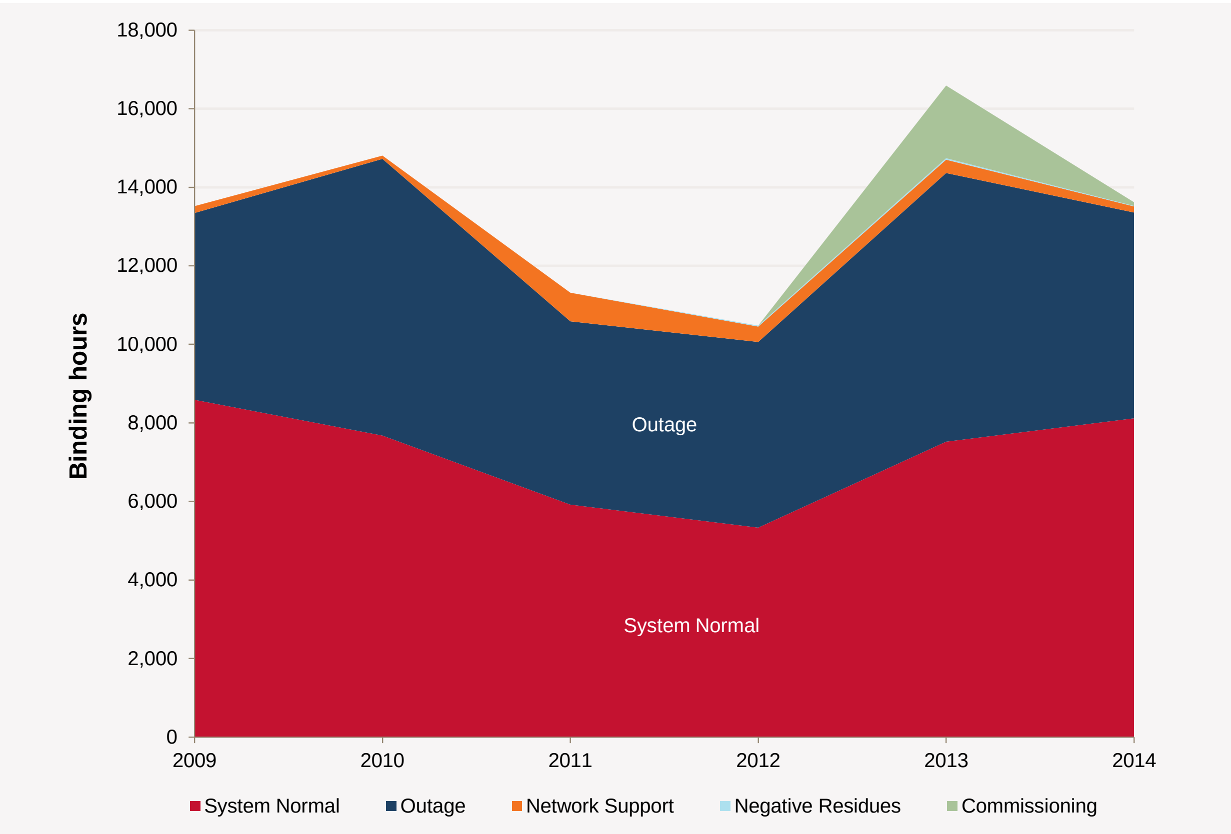


Figure 7 Binding constraint equations by category (system normal; outages)



4. MARKET IMPACT

Binding constraint equations affect electricity market pricing. The relative importance of binding constraints are determined by their market impacts.

The market impact of a constraint is derived by summarising the marginal value for each dispatch interval (DI) from the marginal constraint cost (MCC) re-run[6] over the period considered. The marginal value is a mathematical term for the market impact arising from relaxing the RHS of a binding constraint by one MW. As the market clears each DI, the market impact is measured in $/MW/DI.

The market impact in $/MW/DI is a relative comparison but not otherwise a meaningful measure. However, it can be converted to $/MWh by dividing the market impact by 12 (as there are 12 DIs per hour). This value of congestion is still only a proxy (and always an upper bound) of the value per MW of congestion over the period calculated; any change to the limits (RHS) may cause other constraints to bind almost immediately after.

Table 5 lists system normal constraint equations in bold, and 2013 values in in brackets below the 2014 values.

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 5 Top 20 market impact constraint equations in 2014

Constraint Equation ID (System Normal Bold)	2014 Market Impact (2013 Market Impact)	2014 Hours (2013 Hours)	*Description* Notes
T_TAMARCCGT_GCS	$4,333,860 ($877,585)	503.5 (357.7)	*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
NSA_S_PORxxx	$3,587,599 ($1,796,463)	23.3 (19.4)	*Network Support Agreement for Port Lincoln Units 1 and 2*
S>V_NIL_NIL_RBNW	$2,478,435 ($433,772)	239.8 (51.7)	*Out = Nil, avoid overloading the North West Bend to Robertstown 132 kV line on no line trips* See Table 3 for comments
Q>NIL_TR_TX1_4	$2,171,661 ($1,479,171)	164.8 (120.7)	*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)* See Table 3 for comments
T_MRWF_QLIM_xx	$1,653,083 ($2,720,517)	133.3 (217.3)	*Out = Nil, limit Musselroe Wind Farm based on status of the DVARs, capacitor banks or synchronous condensers at Musselroe* The binding results from the six constraint equations have been combined.
V>>SML_NIL_1	$1,581,992 ($89,828)	28.3 (13.1)	*Out = Nil, avoid overloading Ballarat to Moorabool No.1 220 kV line on trip of parallel No.2 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 Vic to SA (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.

[6] The MCC re-run relaxes any violating constraint equations and constraint equations with a marginal value equal to the constraint equation's violation penalty factor (CVP) x market price cap (MPC). The calculation caps the marginal value in each DI at the MPC value valid on that date (MPC was increased to $13,500 on 1st July 2014).

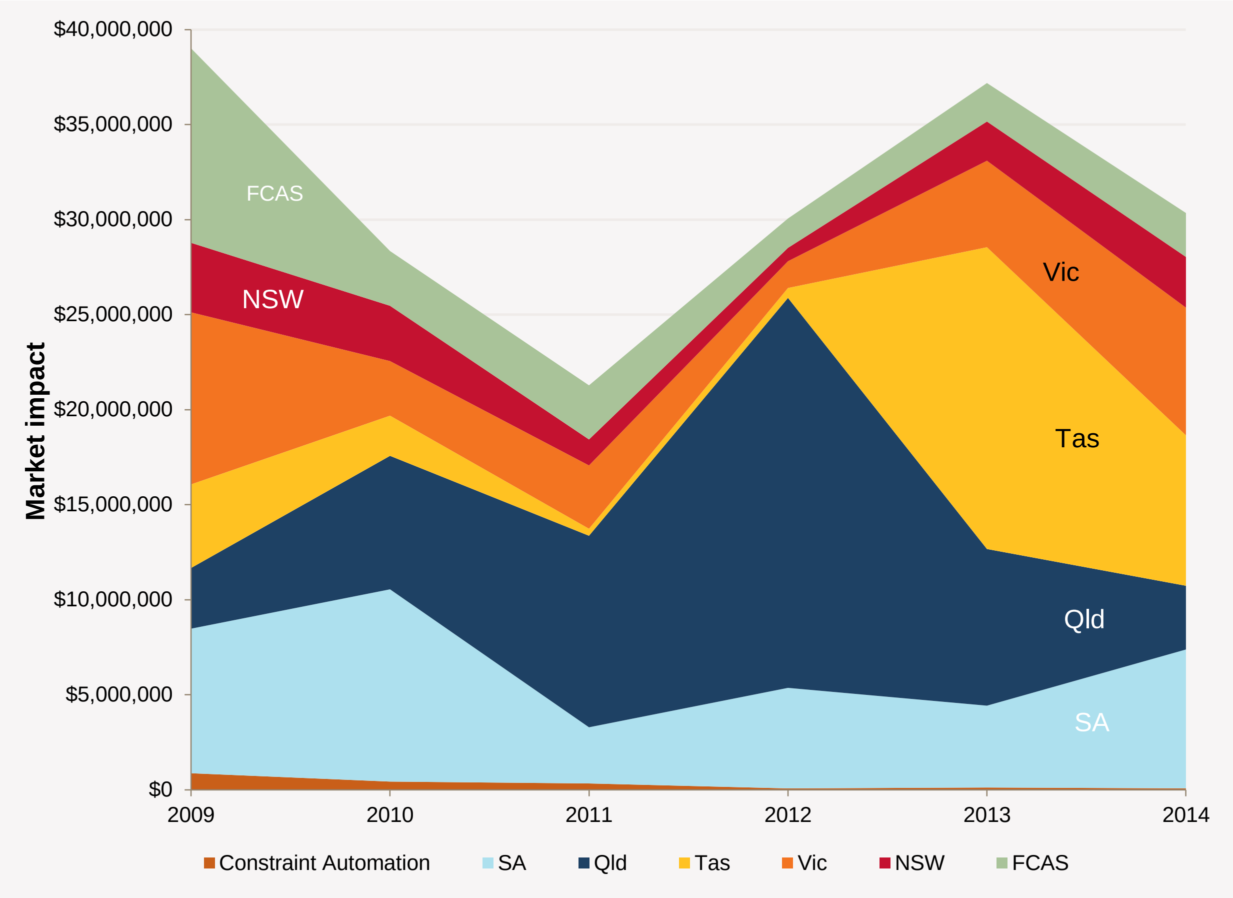
Constraint Equation ID (System Normal Bold)	2014 Market Impact (2013 Market Impact)	2014 Hours (2013 Hours)	*Description* Notes
T>T_NIL_110_1	$1,289,227 ($2,345,388)	104.1 (188.5)	*Out = Nil, avoid overloading the Derby to Scottsdale Tee 110 kV line on no line trips* This constraint equation was implemented in mid-2013 with the Musselroe Wind Farm commissioning. It binds with high output from Musselroe.
V>>SML_NIL_8	$1,181,275 ($593,900)	42.4 (29.3)	*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 Vic to SA (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.
V>>V_NIL_1B	$729,653 ($40,047)	10.6 (14.5)	*Out = Nil, avoid overloading Dederang to Murray No.2 330 kV line for trip of the Dederang to Murray No.1 330 kV line* This constraint equation binds for high transfers from NSW to Victoria with the DBUSS (Dederang bus splitting scheme) active.
N^^V_NIL_1	$701,455 ($28,564)	208.8 (104.0)	*Out = Nil, avoid voltage collapse for loss of the largest Victorian generating unit* See Table 3 for comments
NSA_Q_BARCALDN	$560,383 ($1,856,454)	53.4 (29.5)	*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
V>>V_NIL_3	$556,711 ($41,437)	4.8 (1.3)	*Out = Nil, avoid overloading either Dederang to South Morang 330 kV line for trip of the parallel line*
N^^Q_NIL_B1, 2, 3, 4, 5, 6 and N^Q_NIL_B	$522,292 ($898,361)	72.2 (531.3)	*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.
V_HWMW	$485,500 ($117,900)	3.1 (0.8)	*Out = Hazelwood PS to Morwell PS 220 kV line, Limit Morwell Units 4 and 5 upper limit set to zero*
N>>N-NIL__3_OPENED	$441,872 (0)	4.6 (0)	*Out = Nil, avoid overloading Liddell to Muswellbrook 330kV line (83) on trip of Liddell to Tamworth 330kV line (84)*
V>V_NIL_7	$389,188 ($32,115)	15.8 (2.0)	*Out = Nil, avoid overloading either of Mount Beauty - Dederang 220 kV line for trip of Eildon - Thomastown 220 kV line*
NSA_V_BDL0xxx	$353,989 ($267,895)	5.3 (2.1)	*Bairnsdale Unit 1 or 2 >= various levels for Network Support Agreement* The binding results from xx constraint equations that set the minimum level of Bairnsdale 1 or 2 generation have been combined.
F_T+LREG_0050	$310,122 ($323,429)	735.7 (622.6)	*Tasmania lower regulation requirement greater than 50 MW, Basslink unable to transfer FCAS*
S>>V_NIL_SETX_SETX	$291,351 ($283,673)	517.4 (455.3)	*Out = Nil, avoid overloading a South East 275/132 kV transformer on trip of the remaining South East 275/132 kV transformer* See Table 3 for comments
F_T++NIL_TL_L6	$258,371 ($179,206)	2,401.8 (4,628.3)	*Tasmania lower 6 second requirement for loss of 2 Comalco potlines, Basslink able to transfer FCAS* See Table 4 for comments

4.1 Market Impact Trends

There was a steady decrease in market impacts from 2009[7] to 2011 (see Figure 8). The notable exception was Queensland where market impacts increased over the period. The Queensland increase continued into 2012 and was the primary cause for that year's total market impact increase.

The market impact peaked in 2013 and decreased in 2014 closer to the 2012 level. The main cause of the 2013 peak was the high market impact associated with the Musselroe Wind Farm commissioning.

Figure 8 Market impact by region



From 2009 to 2011, the market impact of system normal constraint equations and outage constraint equations decreased (see Figure 9).

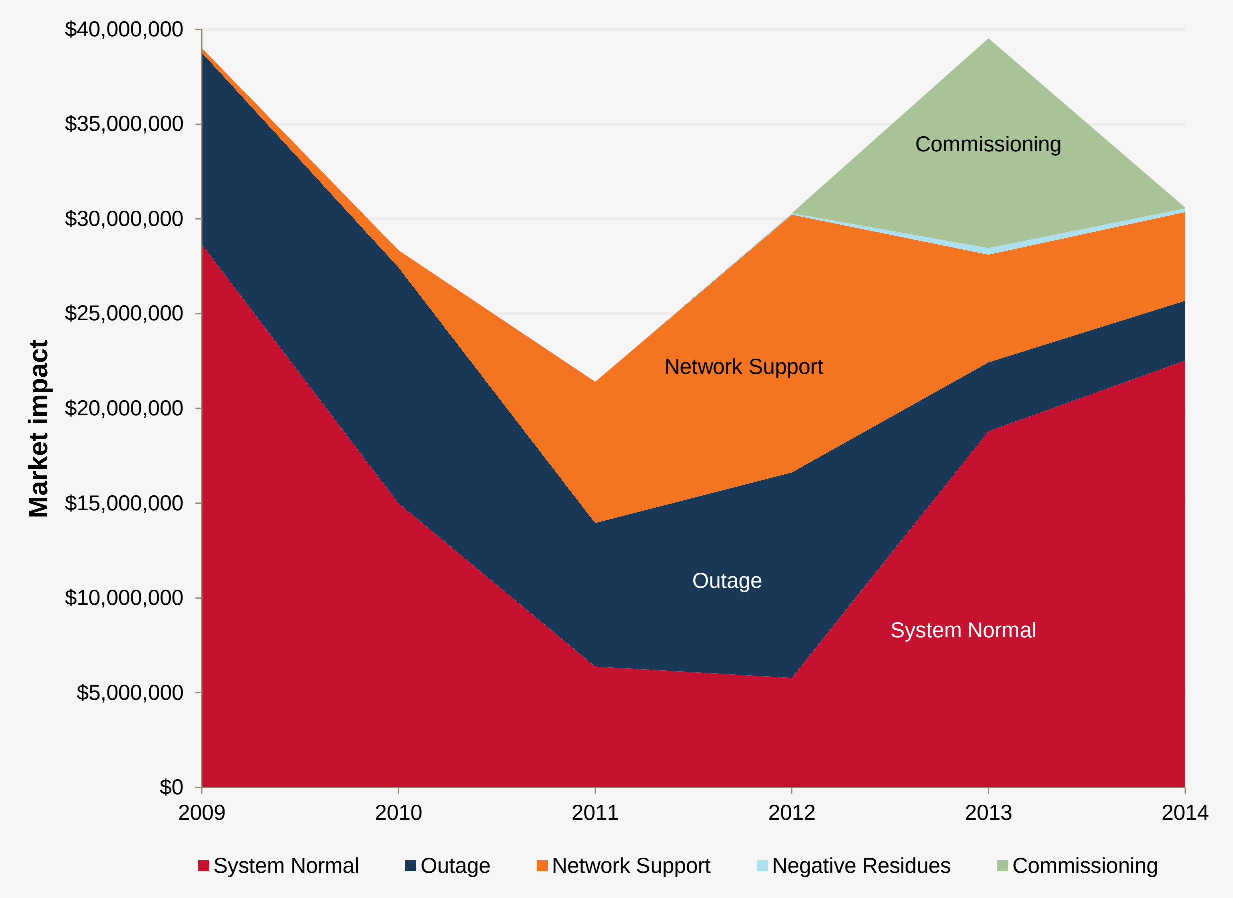
In 2012, network support and outages increased, while system normal slightly decreased.

The network support increase was due to network support agreements in Queensland and South Australia. In 2013 there was a sharp increase in system normal impact and commissioning (due to the 2013 Musselroe commissioning in Tasmania).

In 2014, only system normal increased. This was mainly due to Tamar Valley generation in Tasmania and Robertstown – North West Best 132 kV line protection in South Australia.

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

Figure 9 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.[8]

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 therefore 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. Those that remain are summated as "other".

For comparison, the primary axis shows the summated binding hours for the previous year, while 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 instances 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.

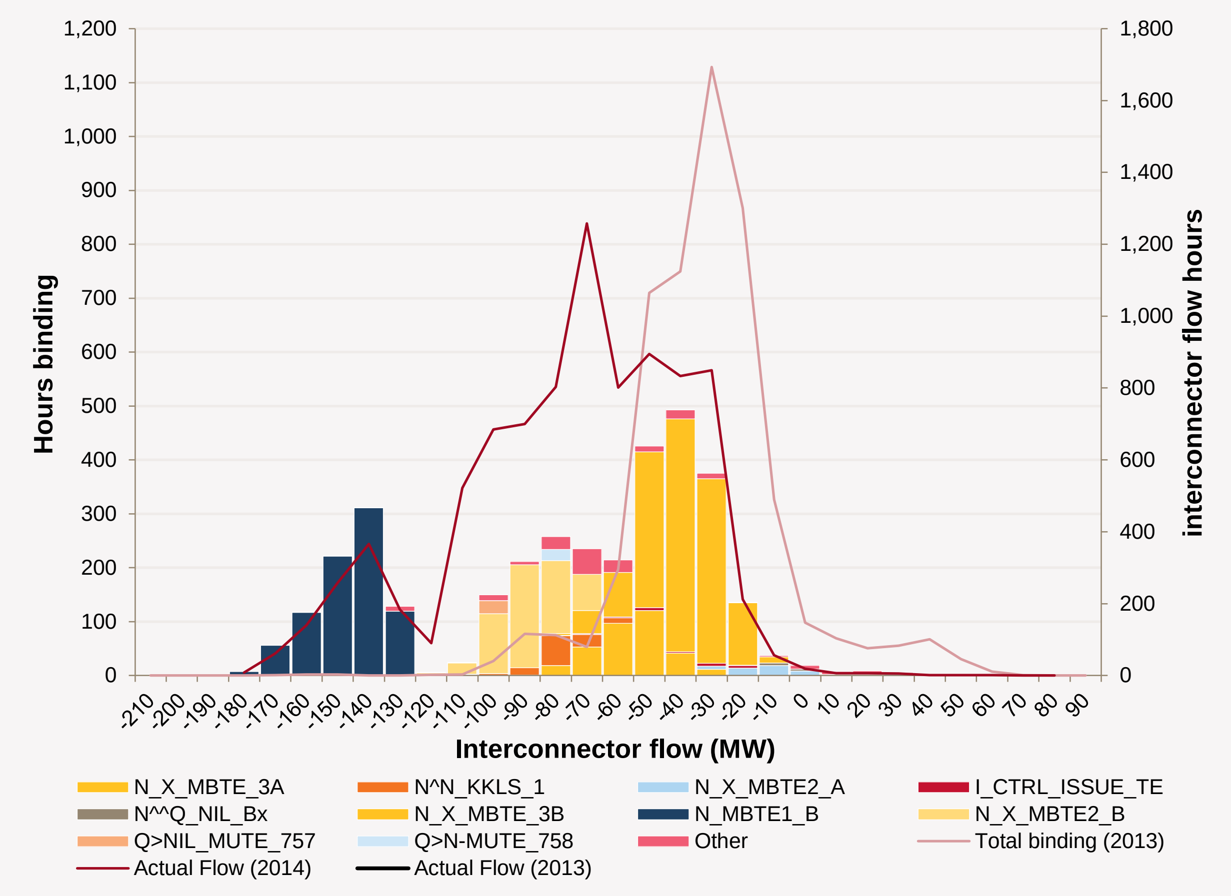
The majority of this interconnector's flows are towards New South Wales, so both the import and export values are negative (unlike the other NEM interconnectors). It is usually constrained by thermal limits in northern New South Wales (N>N-NIL_LSDU) or by rate of change on Directlink (NQTE_ROC, QNTE_ROC).

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 and N^Q_NIL_B and N^Q_NIL_A).

In 2014, most of the time Terranora was restricted was due to the outage of all three Directlink cables or outages of a single Directlink cable (see Figure 10).

[8] For more information about the limits of each interconnector, see: http://www.aemo.com.au/Electricity/Resources/Reports-and-Documents/Network-Operations/~/media/Files/Other/planning/gsoo/2014/Interconnector_Capabilities_v1_july_2014.ashx

Figure 10 Binding constraint equation distribution for N-Q-MNSP1



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

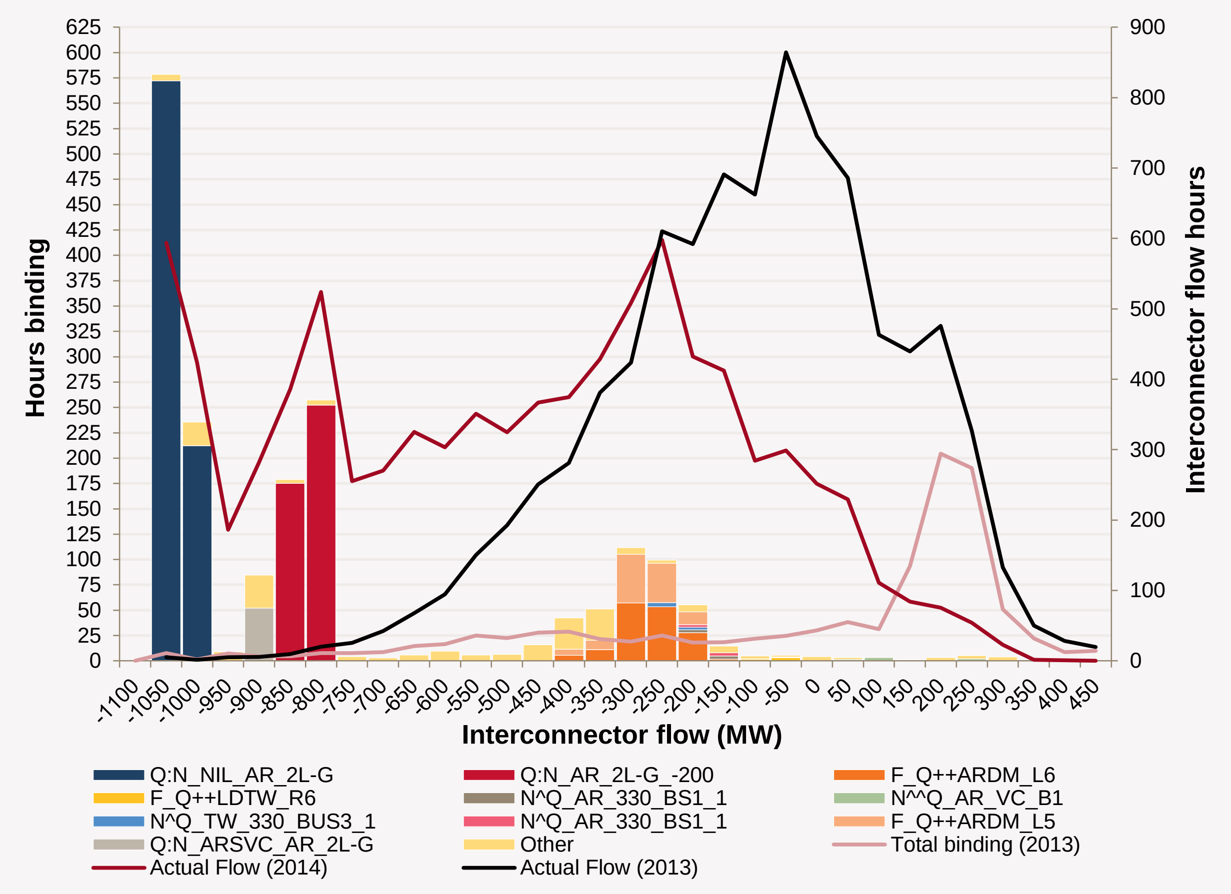
The Queensland to New South Wales interconnector (QNI) is a 330 kV AC interconnection between Dumaresq in New South Wales and Bulli Creek in Queensland. It was commissioned in 2001 as a double-circuit 330 kV line between Armidale and Braemar, and a double-circuit 275 kV line between Braemar and Tarong. Due to their close electrical proximity on the New South Wales side, both QNI and Terranora often appear on the LHS of constraint equations.

Historically, the 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 and 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 a 2L-G fault between Armidale and Bulli Creek, or by 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. Following revised limit advice from Powerlink in 2014, the transient stability constraint equation was renamed to reflect the most critical contingency moving closer to Armidale.

Historically, the majority of flows are greater than 500 MW from Queensland into New South Wales. However, in 2013, the majority of flows shifted to 150 to 250 MW flows into Queensland from New South Wales. In 2014, the flows reverted to their historical normal of mainly from Queensland to New South Wales, albeit at a lower values between 200 and 350 MW into New South Wales (see Figure 11). The most constrained flows were between 750 and 1,100 MW into New South Wales from Queensland.

Figure 11 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 of these interconnectors can be limited due to the same network limitation.

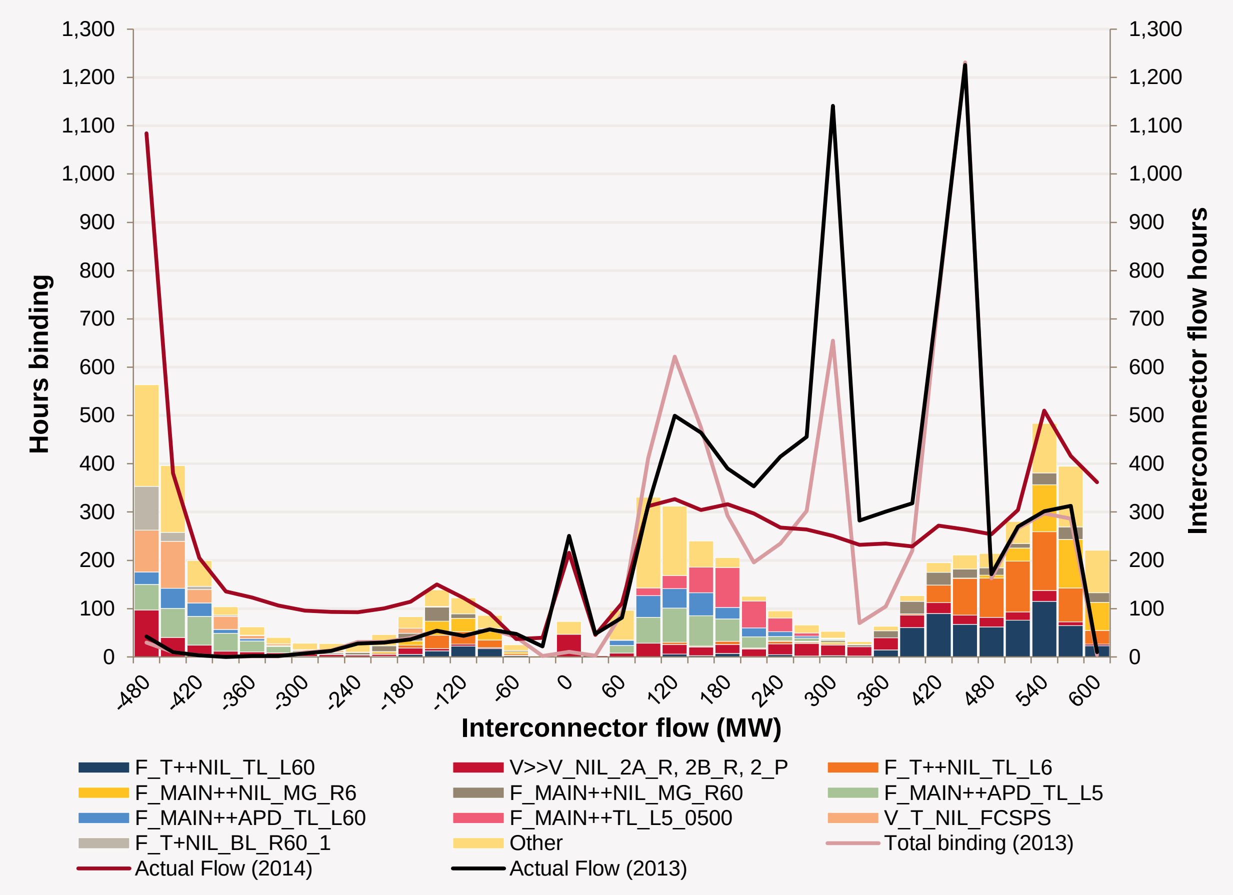
The majority of the limitations on Basslink transfers are due to FCAS constraint equations for both mainland and Tasmanian contingency events.

Tasmania to Victoria transfers are mainly limited by the energy constraint equations for the South Morang F2 transformer overload (V>>V_NIL_2A_R and V>>V_NIL_2B_R and 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).

In previous years, the majority of flows and binding hours on Basslink were from Tasmania to Victoria. In 2014, this reversed with nearly 1,100 hours of flows of 480 MW into Tasmania (most in the second half of 2014). There was still a large number of binding hours from Tasmania to Victoria (see Figure 12).

Figure 12 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. It replaced the previous "SNOWY1" and "V-SN" interconnectors. VIC1–NSW1 appears in many of the Victorian constraint equations along with the other interconnections to Victoria (Basslink, V-SA, and Murraylink). This can lead to situations where many or all of these interconnectors can be limited due to the same network limitation.

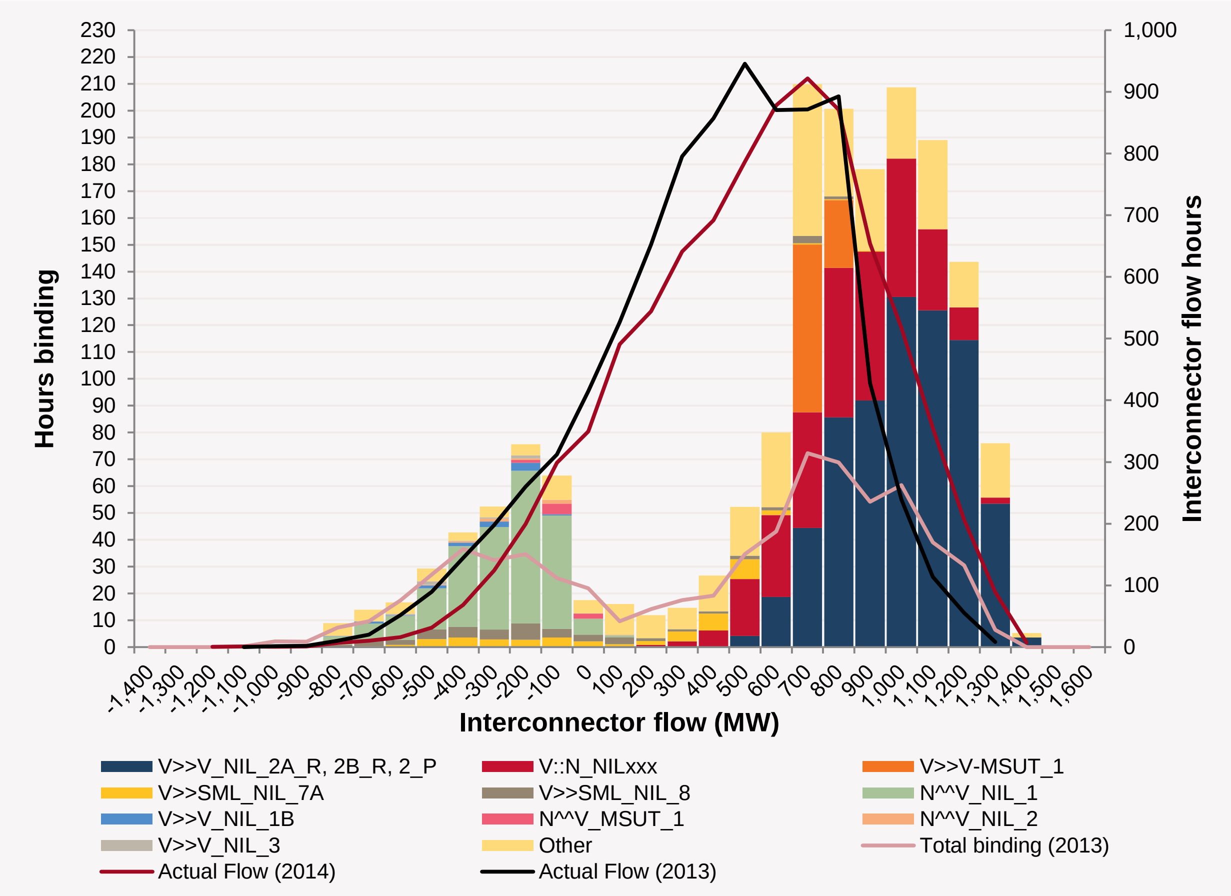
VIC1–NSW1 can bind in either direction for high demand in New South Wales or Victoria. Transfer from Victoria to New South Wales is mainly limited by the thermal overload limits on the South Morang F2 transformer (V>>V_NIL_2A_R and V>>V_NIL_2B_R and V>>V_NIL_2_P), the South Morang to Dederang 330 kV 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, since mid-2012 these constraint equations have rarely bound.

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

In both 2013 and 2014, the hours at each flow level and the binding hours on VIC1–NSW1 were similar. The main difference in 2014 (compared to 2013) was that the high flow levels into New South Wales were constrained for a larger number of hours. This is shown in Figure 13.

Figure 13 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 the South East of South Australia.

It was originally commissioned in 1989 as a connection from the western 500 kV network in Victoria to Para, the nearest 275 kV substation in South Australia. It includes a number of connections to the parallel 132 kV network in south-eastern South Australia. 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.

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

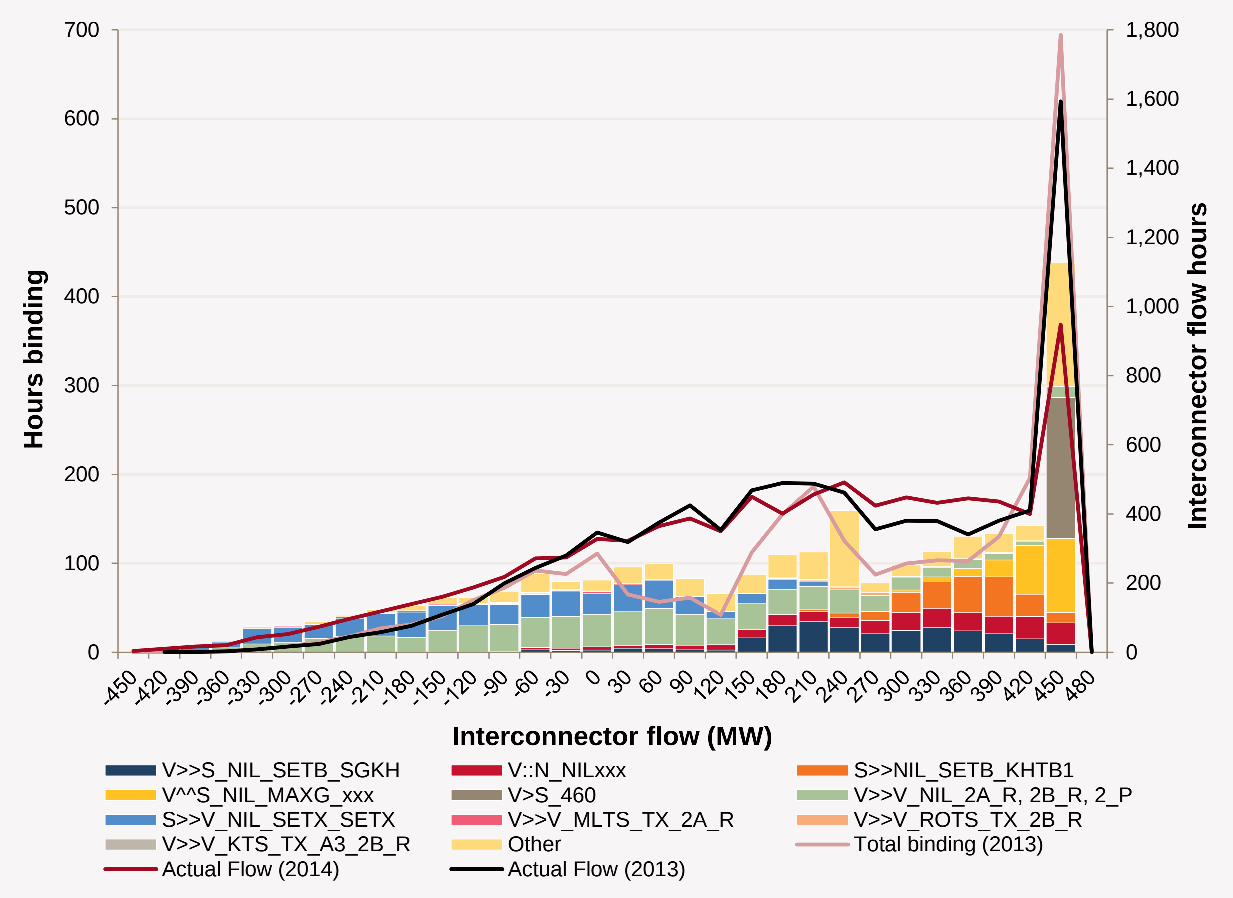
From 2011 to 2013, there was a series of increases to the voltage collapse limit for loss of the largest South Australian generator (V^^S_NIL_MAXG_xxx) causing this limit to bind less often (1,026 hours in 2011; 220 in 2012; 209 in 2013 and down to 173 in 2014).

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 and V>>V_NIL_2B_R and V>>V_NIL_2_P).

The hours at each flow level on V-SA were very similar in 2013 and 2014 with the exception of less hours for high flows into South Australia (at the 450 MW flow level). There was also a corresponding decrease in the binding hours in at the 450 MW flow level compared to those of 2013. This is reflected in Figure 14.

Figure 14 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 (V>>V_NIL_2B_R and V>>V_NIL_2_P).
- Ballarat North to Buangor 66 kV line (V>>SML_NIL_7A).
- South Morang to Dederang 330 kV line (V>>V_NIL1A_R).
- Ballarat to Bendigo 220 kV line (V>>SML_NIL_8).

Alternatively by the 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).[9]

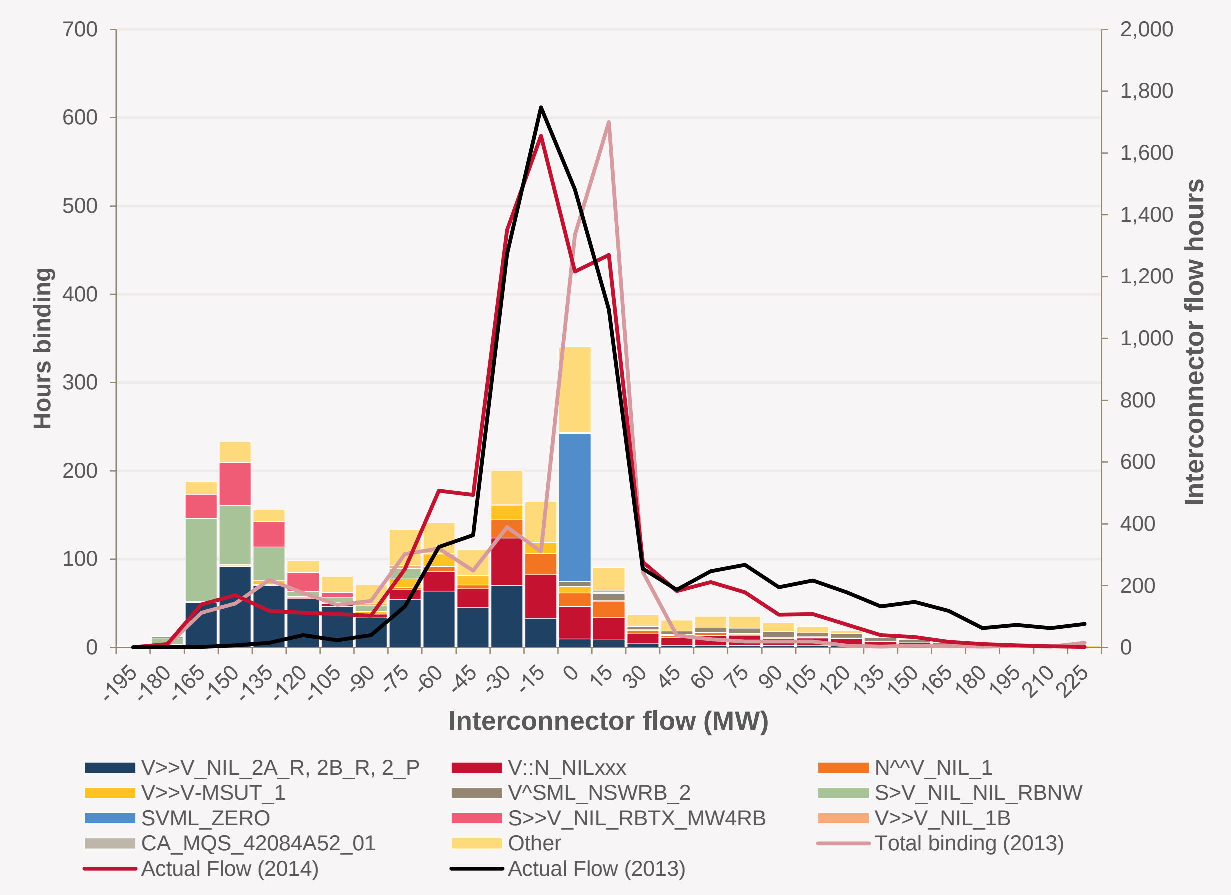
Transfers from South Australia to Victoria on Murraylink are limited by thermal overloads on the:

- Robertstown to Monash 132 kV lines (S>V_NIL_NIL_RBNW).
- Dederang to Murray 330 kV lines (V>>V_NIL_1B).
- Robertstown transformers (S>>V_NIL_RBTXW_RBTX1).

In 2014 and 2013, the number of hours at each flow level on Murraylink was very similar. The main difference in 2014 was an increase at higher flows into Victoria, and a decrease in binding hours at 0 MW (due to a shorter outage of Murraylink). This amounted to 10 days in 2014 compared with 27 days in 2013m abd is shown in Figure 15.

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

Figure 15 Binding constraint equation distribution for Murraylink



6. TRANSMISSION OUTAGES

This chapter details the major transmission outages in 2014, and a comparison of the outage submission and start times for each TNSP.

6.1 Major outages

Table 6 shows the duration of 2014 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 Top 40 outages associated with binding constraint equations

Constraint Set ID	2014 Days (2013 Days)	Outage Notes
N-MBTE_1	365.0 (0)	*One Directlink cable*
N-X_MBTE_2	169.8 (214.9)	*Two Directlink cables*
Q-X_BC_CB8L2_CB99012	130.9 (0)	*Bulli Creek CBs (8L2 and 99012) or (8M2 and 99022)*
N-LSLS_9U8	109.4 (0)	*One Lismore 330 to Lismore 132 (9U8 or 9U9 or 9W1) 132 kV line*
N-X_MBTE_3	70.3 (158.1)	*All three Directlink cables*
F-I_TL_0500	55.3 (0)	*FCAS Lower Requirements for a NEM Network Event, TL = 500*
V-HWMW	44.0 (0)	*Outage of Hazelwood PS to Morwell PS 220 kV line*
Q-BCKBR_9901_9902	40.9 (0)	*One Bulli Creek to Braemar (9901 or 9902) 330 kV line*
F-I_ML_APD	38.2 (0)	*Out=Nil, Dynamic FCAS for APD Load Event*
I-MSUT	16.7 (9.0)	*Murray to Upper Tumut (65) 330 kV line*
V-MLTX_R	15.4 (0)	*Outage = Moorabool (A1 or A2) 500/220kV transformer, Radial Mode*
V-KTTX_A2_OR_A4_R	13.9 (0)	*Outage = Keilor 500/220kV A2 or A4 transformer, Radial*
I-ML_ZERO	10.0 (27.2)	*Limit Murraylink to zero in either direction*
N-AR_VC1	9.9 (0)	*Armidale SVC*
F-I-BCDM_ONE	9.8 (1.1)	*One Bulli Creek to Dumaresq 330 kV line - FCAS Requirements*
I-BCDM_ONE	9.8 (1.1)	*One Bulli Creek to Dumaresq 330 kV line*
N-KKLS_967	9.3 (3.8)	*Koolkhan to Lismore (967) 132 kV line*
V-KTTX_A3_R	7.4 (0)	*Outage = Keilor 500/220kV A3 transformer, Radial*
V-HWSM	7.2 (2.5)	*Hazelwood to South Morang 500 kV line*
I-HYSE	4.9 (22.6)	*One Heywood to South East 275 kV line*
Q-GB_VC	4.7 (0)	*Greenbank SVC*
V-HYTX	4.6 (21.6)	*One Heywood 500/275 kV (M1 or M2) transformer*
V-SMSY	4.0 (0)	*One South Morang to Sydenham 500 kV line*
V-MLSY	3.8 (0)	*Moorabool to Sydenham 500 kV line*
N-ARTW_85	3.4 (0.3)	*Armidale to Tamworth (85) 330 kV line*
V-EPMB	3.3 (0)	*Outage = Eildon to Mt Beauty 220kV line*
S-DVCN	3.3 (0)	*Davenport to Canowie 275 kV line*
Q-BK_VC	3.1 (0)	*Blackwall SVC*
N-LTYS_03	2.9 (0)	*Lower Tumut to Yass (3) 330 kV line*
N-LSTN_96L	2.8 (0)	*Lismore to Tenterfield (96L) 132 kV line*
S-RBPA	2.8 (0)	*Out= Robertstown - Para 275 kV line*
I-LTMS	2.8 (0)	*Lower Tumut to Murray (66) 330 kV line*
Q-SP_VC	2.5 (0)	*South Pine SVC*
N-LDTW_84	2.5 (0)	*Liddell to Tamworth (84) 330 kV line*

Constraint Set ID	2014 Days (2013 Days)	Outage Notes
S-BNMT	2.3 (4.5)	*Blanche to Mt Gambier 132 kV line*
NSA-Q_BARCALDN	2.2 (1.2)	*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
N-ARDM_ONE	2.2 (0)	*One Armidale to Dumaresq (8C or 8E) line*
F-N-ARDM_ONE	2.2 (1.1)	*One Armidale to Dumaresq (8C or 8E) 330 kV line*
V-DDSM	2.1 (0)	*One Dederang to South Morang 330 kV line*
V-EPTT_R	2.1 (1.2)	*Eildon to Thomastown 220 kV line*

6.2 Trends for submit times

Figure 16 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 its start time.
- ≤ 30 days: the outage was submitted within 30 days of its start time.
- 30 days: the outage was submitted more than 30 days before its start time.

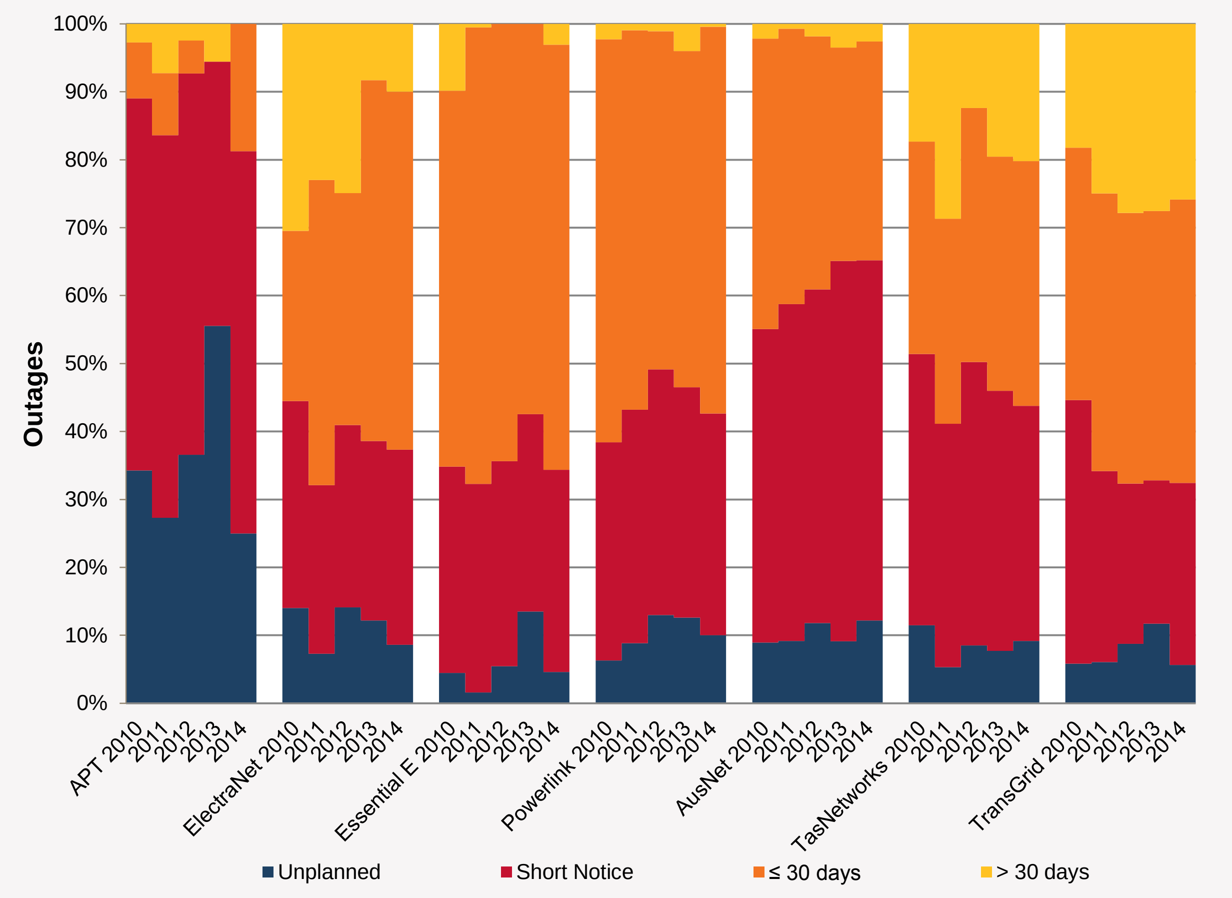
Outages that were previously submitted and then rescheduled for a new time are recorded as new outages in the NOS. Outages for multiple items of related plant that are submitted in a single entry are only counted as a single outage.

Australian Pipeline Trust (APT), Essential Energy, TransGrid, and TasNetworks submit their 13-month outage plans via NOS. Powerlink, ElectraNet, and AusNet Services submit their 13-month outage plans as spreadsheets and they are not included in these statistics.

AEMO has observed the following trends:

- Since 2010, more than 80% of APT outages are unplanned or short notice. (APT operates the Murraylink and Directlink HVDC interconnectors.)
- For other NSPs, less than 13% of outages are forced. The majority of the outages are either short notice or within 30 days.
- Compared to other TNSPs, TransGrid and TasNetworks have a higher percentage of their outages submitted more than 30 days before the start time.
- Very few outages are submitted by Essential Energy, Powerlink, AusNet Services, or APT for more than 30 days out. For Powerlink and AusNet Services this can be explained by the fact that their submitted 13-month outage plans submitted as spreadsheets are not included in these statistics.
- The percentage of outages submitted by ElectraNet more than 30 days from the start time has decreased.

Figure 16 Outage submit times versus start time



7. MEASURES AND ABBREVIATIONS

7.1 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. It measures the rate of energy conversion or transfer. A Megawatt is one million watts.

7.2 Abbreviations

Abbreviation	Expanded name
CVP	Constraint violation penalty factor
DI	Dispatch Interval
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
NSA	Network Support Agreement
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.