NEM CONSTRAINT REPORT 2015

FOR THE NATIONAL ELECTRICITY MARKET

Published: **May 2016**

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 2015 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. 2015 had the largest number of constraint equation changes since the start of the National Electricity Market (NEM) (see chapter 2).
2. The market impact due to binding constraints was the highest since the data became available in 2009 (see chapter 4). This was primarily driven by Frequency Control Ancillary Service (FCAS) costs in South Australia and network support agreements in Queensland.

Year	Constraint changes	Market impact ($/MW/DI)
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
2015	11,967	$46.6 million

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1. CURRENT CONSTRAINT STATISTICS

At 31 December 2015, the total number of constraint sets, equations, and functions available in AEMO's electricity market management system (MMS) were:

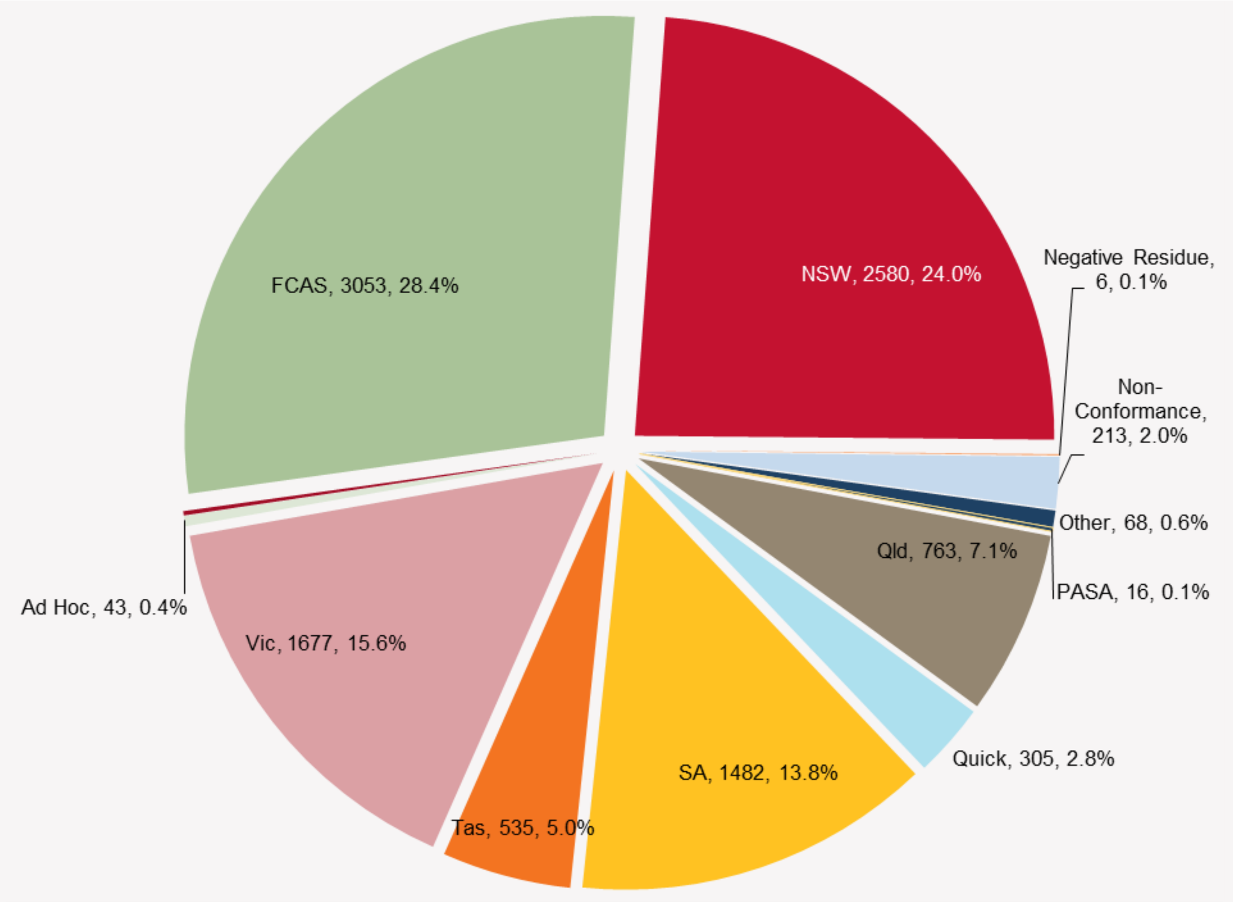
- 3,629 constraint sets: up from 3,424 in the previous year
- 11,230 constraint equations: up by 927 from the previous year's 10,303
- 364 constraint functions: up by 5 from 359 in the previous year.

Excluded from these totals are any constraint sets, equations, or functions archived before December 2015, and any 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 excluded from the above results.

Figures 1 and 2 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, FCAS, non-conformance, and miscellaneous constraint types (Figure 1), and by limit type (Figure 2).

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



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

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

Figure 2 below shows that the main types of constraint equations are for thermal overloads (35%) and FCAS (19.9%).

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.

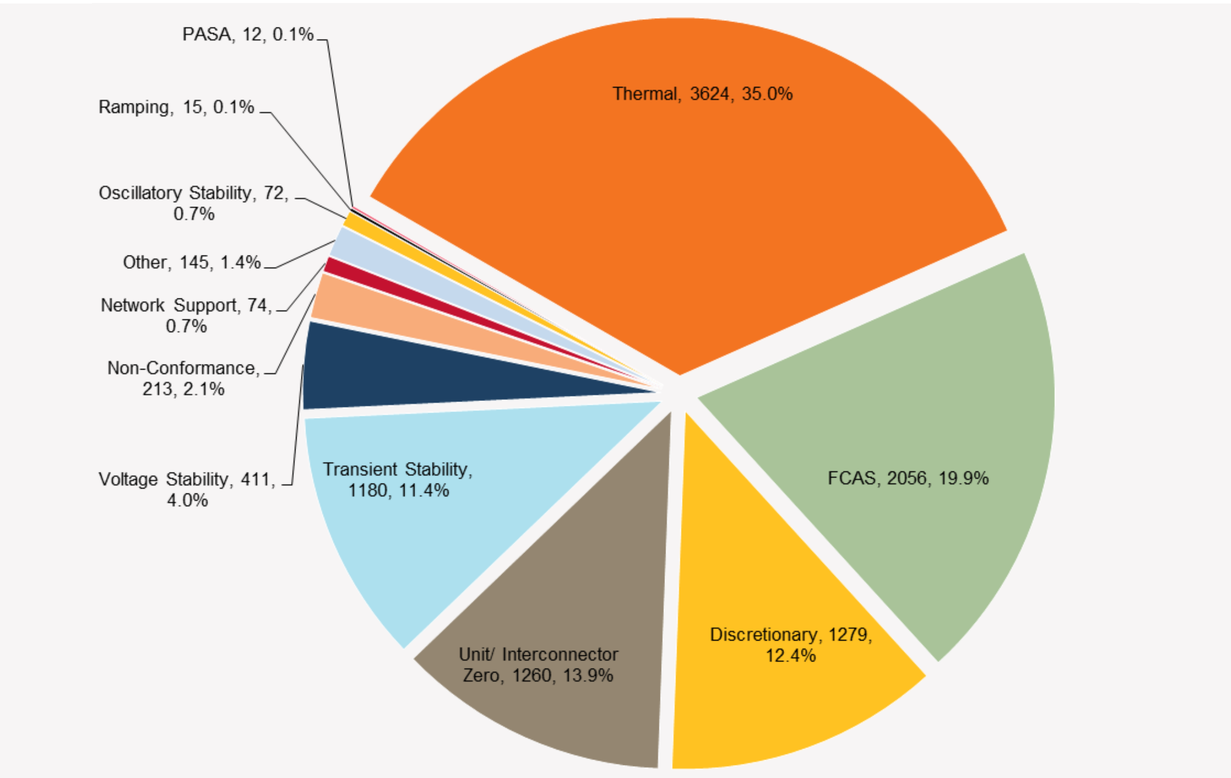
Ad hoc constraint equations are also created by AEMO's control room staff. These are mainly created for a large number of LHS terms. The software that creates quick constraints now handles more complex LHSs, so ad hoc constraint equations are rarely built.

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 2015, compared with the previous year, specifically:

- NSW increased from 2,462 to 2,580.
- FCAS constraint equations increased from 2,907 to 3,053
- Victoria increased from 1,421 to 1,677.
- South Australia increased from 1,003 to 1,482.
- Total thermal constraint equations increased from 2,948 to 3,624. This is attributed to the increase in South Australian and Victorian constraint equations.

Figure 2 Constraint equations by limit type



2. CONSTRAINT EQUATION CHANGES

A main driver for new or updated constraint equations 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 2015 the number of constraint equation changes was the highest since the start of the national electricity market (NEM). The major contributors to the high number were generator changes in NSW and Victoria.

2.1 Generators added or removed in 2015

The following list includes all scheduled and semi-scheduled generators either added to the power system in 2015, or removed. It also includes non-scheduled plant large enough to have caused constraint equation changes.

In 2015 there were only two new generators registered and a re-registration of Laverton North and Valley Power to disaggregate. The number of new registrations was the equal lowest since 2010. (There were four in 2010, five in 2011, two in 2012, five in 2013, and three in 2014).

The disaggregation of Laverton North and Valley Power had a large impact on Victoria. It was the major contributor to the 3541 constraint equation changes in Victoria – the highest number ever.

In NSW, deregistration of Wallerawang 8 on 30 December 2014 caused changes to constraint equations well in to 2015.

The new Broken Hill solar farm caused many constraint changes in both NSW and Victoria – a rarity in the NEM as normally generators only affect constraint equations in their region.

Table 1 Generator changes in 2015

Generator	Registration Date	Region	Notes
Redbank Unit 1	2 January 2015	NSW	Suspended
Bald Hills Wind Farm	29 January 2015	Vic	
Laverton North GT (2 Aggregated Units)	1 July 2015	Vic	De-registered
Valley Power GT (6 Aggregated Units)	1 July 2015	Vic	De-registered
Laverton North GT Unit 1 and 2	1 July 2015	Vic	Laverton North re-registered from an aggregate unit to 2 units
Valley Power GT Unit 1, 2, 3, 4, 5 and 6	1 July 2015	Vic	Valley Power re-registered from an aggregate unit to 6 units
Broken Hill Solar Farm	25 August 2015	NSW	New Generator
Anglesea	1 September 2015	Vic	De-registered

2.2 Transmission changes in 2015

In 2015, the number of transmission changes decreased to 27 (from 30 in 2014, 28 in 2013, 19 in 2012, 21 in 2011, and 17 in 2010). While a number of these changes caused constraint changes – these were dwarfed by changes due to generators.

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

Table 2 Transmission changes in 2015

Generator	Registration Date	Region	Notes
Tungatinah to Meadowbank to New Norfolk No. 2 110 kV line	25 April 2015	Tas	Part of larger project - the rearrangement of Tarraleah and Tungatinah substations
Tungatinah to Meadowbank to New Norfolk No. 1 110 kV line	28 April 2015	Tas	Part of larger project - the rearrangement of Tarraleah and Tungatinah substations
Tungatinah to New Norfolk No. 3 110 kV line	17 April 2015	Tas	Part of larger project - the rearrangement of Tarraleah and Tungatinah substations
Tungatinah to New Norfolk No. 1 110 kV line decommissioned	17 April 2015	Tas	Part of larger project - the rearrangement of Tarraleah and Tungatinah substations
Wotonga 132 kV substation	07 May 2015	Qld	Moranbah to Wotonga (7413) 132 kV line and Nebo to Wotonga tee Coppabella (7118) 132 kV line commissioned.
Blackstone to Blackwall (8821) 275 kV line	12 June 2015	Qld	
Blackstone to Greenbank (8888) 275 kV line	12 June 2015	Qld	
Heywood No.1 275 kV bus	15 June 2015	Vic	
Swanbank E to Blackstone (8826) 275 kV line	26 June 2015	Qld	
Blackstone No. 1 275/110 kV transformer	30 June 2015	Qld	
Eurombah to Yuleba North (8901) 275 kV line	15July 2015	Qld	
Wandoan South to Yuleba North (8899) 275 kV line	13 July 2015	Qld	
Eurombah to Yuleba North (8900) 275 kV line	16 July 2015	Qld	
Yuleba North substation	16 July 2015	Qld	Yuleba North No.1 and No. 2 275/132 kV transformers and No.1 and No.2 132 kV buses
Dinoun South to Yuleba North (7420) 132 kV line	21 July 2015	Qld	
Eurombah No.1 and No.2 132 kV buses	20 July 2015	Qld	
Dinoun South to Yuleba North (7419) 132 kV line	28 July 2015	Qld	
Munno Para 275 kV substation	29 July 2015	SA	New Munno Para substation cut into Blyth West to Para 275 kV line
Wandoan South to Yuleba North (8898) 275 kV line	29 July 2015	Qld	
Ross No.2 275 kV 100 MVar reactor	14 August 2015	Qld	
Clifford Creek 132 kV substation	12 August 2015	Qld	Clifford Creek No.1 and 2 132 kV buses and both Clifford Creek to Yuleba North (7421 and 7422) 132 kV lines
Abermain to Blackstone (8884) 275 kV line	06 November 2015	Qld	
Nebo to Pioneer Valley (7305) 132 kV line	10 November 2015	Qld	Nebo to Mackay (7305) 132kV line cut into Pioneer Valley
Fairview substation	12 November 2015	Qld	Fairview No.1 and 2 132 kV buses and both Fairview South to Fairview (7427 and 7428) 132 kV lines
Blackstone No.2 275/110 kV transformer	13 November 2015	Qld	
South East 275 kV circuit breakers	Late November 2015	SA	Increases 275 kV bus coupling options at South East and removes a number of outage constraint equations.

Generator	Registration Date	Region	Notes
Heywood No.3 500/275 kV transformer	15 December 2015	Vic	Heywood Terminal Station 500 kV Bus Tie and No.3 transformer. Part of the Heywood upgrade project[2].

2.3 Comparisons of constraint equation changes

Figure 3 compares annual constraint equation changes by region. It also compares 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, an FCAS change made active on 1 Jan 2009 but loaded into the database in late-2008, is included in the 2008 results – not the 2009 results.

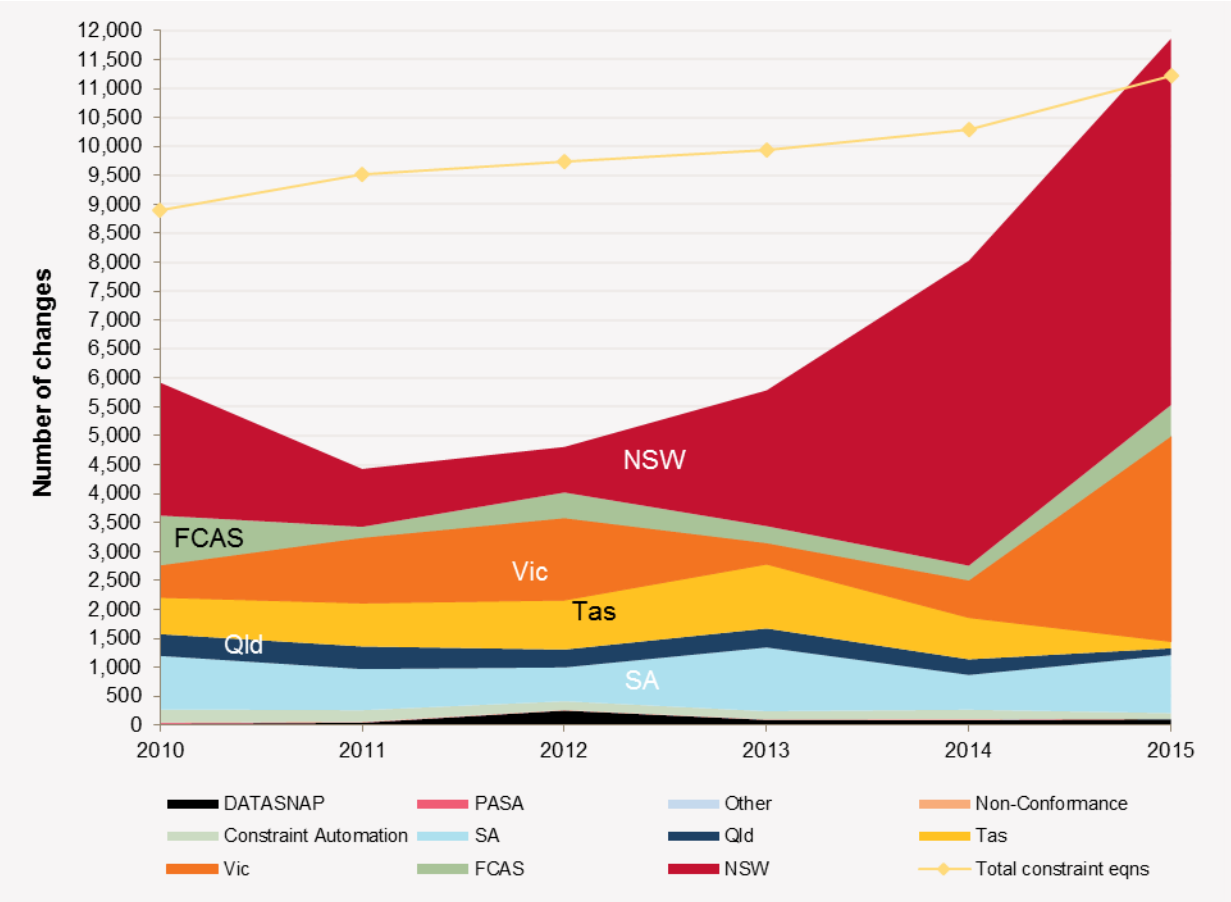
The number of changes for 2013 does not include changes due to the constraint violation penalty factor (CVP) update in August 2013[3], which required 8,833 constraint equation updates. Nor does it include changes due to real time constraint automation.[4]

[2] AEMO. *Heywood Interconnector RIT-T*. Available at http://www.aemo.com.au/Electricity/Planning/Regulatory-Investment-Tests-for-Transmission/Heywood-Interconnector-RIT-T. Viewed: 2 March 2016.

[3] 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.

[4] 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.

Figure 3 Constraint equation changes per calendar year, 2010 to 2015



As shown in Figure 3, total constraint equation changes in 2015 (11,967) were the highest since the start of the NEM. The previous highest was 8594 in 2009 – due mainly to abolition of the Snowy region[5] and frequency standard change in Tasmania. In 2015, New South Wales again dominated with 53% of the changes (down from 65% in 2014) followed by Victoria with 30%.

The 11,967 changes in 2015 were well above the 10-year average of 6,340. In the past five years, the number of changes was due to:

- 2010: multiple stages of the New South Wales western 500 kV project.
- 2013: changes to operating margins across multiple regions; Gullen Range Wind Farm in New South Wales; and Musselroe Wind Farm in Tasmania.
- 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.
- 2015: Registration of solar farms in NSW (work due to Nyngan continued) and Broken Hill; new wind farm at Bald Hills; the disaggregation of Laverton North and Valley Power; and de-registration of Anglesea.

[5] Prior to 1 July 2008 the Snowy region existed between NSW and Victoria. It contained the Murray, Lower Tumut, Upper Tumut and Guthega generators. After a review the region was removed and the generators moved into NSW and Victoria. This also created a new interconnector VIC-NSW1 which replaced the previous two interconnectors V-SN and SNOWY1. This change caused a large number of constraint equation changes.

3. BINDING

This chapter examines the top 20 binding constraint equations in 2015. A constraint equation is binding when the power system flows it manages reach their applicable thermal or stability limits, or when the constraint equation is setting an FCAS requirement. When a constraint equation is binding, NEMDE has changed the generator and interconnector targets to satisfy the constraint equation. 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 binding results, so 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 2014 (if any) is indicated in brackets below the 2015 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[6] or via the MMS data model.[7]

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 are not those for outage cases.

3.1 Network constraint equations

Table 3 Top 20 binding network constraint equations

Constraint Equation ID (System Normal Bold)	2015 Hours (2014 Hours)	*Description* Notes
N_X_MBTE_3A & N_X_MBTE_3B	1,312 (1,662)	*Out = all three Directlink cables* All three Directlink cables was out for 55.1 days in 2015 compared to 70.3 days in 2014. See Table 6.
V::N_NIL_xxx	1,091 (317)	*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.
N_X_MBTE2_A & N_X_MBTE2_B	1,044 (580)	*Out = two Directlink cables* Two Directlink cables was out for 251.4 days in 2015 compared to 169.8 days in 2014. See Table 6.

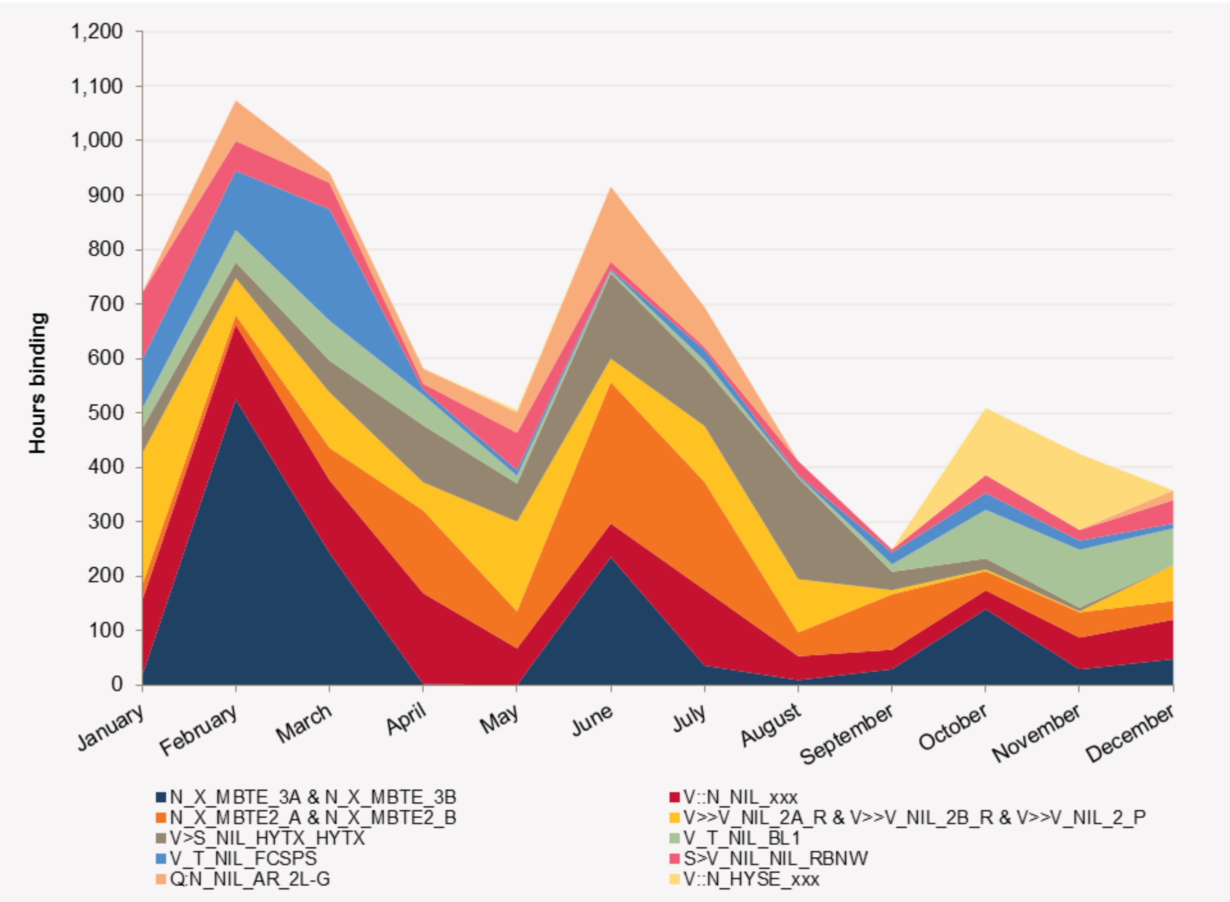
6 Available at: https://mms.prod.nemnet.net.au/Mms/login.aspx.

7 Available at: http://www.aemo.com.au/About-the-Industry/Information-Systems/Data-Interchange.

Constraint Equation ID (System Normal Bold)	2015 Hours (2014 Hours)	*Description* Notes
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	951 (844)	*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.
V>S_NIL_HYTX_HYTX	819 (474)	*Out = Nil, avoid overloading the remaining Heywood 275/500 kV transformer on trip of one Heywood 275/500 kV transformer* This constraint equation was removed with the commissioning of the third Heywood 275/500 kV transformer in December 2015.
V_T_NIL_BL1	537 (164)	*Out=Nil, Basslink no go zone limits Victoria to Tasmania*
V_T_NIL_FCSPS	526 (335)	*Basslink limit from Victoria to Tasmania for load enabled for the Basslink frequency control special protection scheme (FCSPS)* This constraint equation binds when there is high import to Tasmania or a low amount of load is enabled for tripping.
S>V_NIL_NIL_RBNW	452 (242)	*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.
Q:N_NIL_AR_2L-G	388 (800)	*Out = Nil, avoid transient instability for a 2 line to Ground fault at Armidale*
V::N_HYSE_xxx	266 (0)	*Out = Heywood to South East 275 kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500 kV line* One Heywood to South East 275 kV line was out for 28.3 days in 2015 compared to 4.9 days in 2014. See Table 6.
V>>S_NIL_SETB_SGKH	265 (288)	*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.
V>S_460	261 (159)	*VIC to SA on Heywood upper transfer limit of 460 MW* With the commissioning of the third 500/275 kV transformer this limit was lifted to 500 MW on 23 December 2015 and to 570 MW on 17 February 2016.
Q>NIL_BI_FB	259 (1,063)	*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::S_NIL_MAXG_xxx	243 (0)	*Out = Nil, avoid transient instability for trip of the largest generation unit in South Australia* There are two constraint equations that make up the transient stability export limit from Victoria to South Australia and all the binding results have been combined. AEMO expects this limit will bind at higher levels in 2016 due to lifting of the 460 MW limit. This will continue until the Heywood upgrade is completed in mid-2016.
N^^V_NIL_1	212 (210)	Out = Nil, avoid voltage collapse for loss of the largest Victorian generating unit
V>>S_HYML_1	210 (20)	*Out = Heywood to Moorabool to Alcoa Portland 500 kV line, avoid overloading Heywood 500/275 kV (M1 or M2) transformer for trip of Northern Power Station unit 1* The Heywood to Mortlake No.2 500 kV line was out for 1.9 days in 2015 compared to 0.3 days in 2014. See Table 6.
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	177 (72)	*Out = Nil, avoid voltage collapse for loss of the largest Queensland generator* This voltage collapse limit is split into 7 constraint equations to co-optimise with each of the 6 largest generators in Queensland. Overall N^^Q_NIL_B1 (for trip of Kogan Creek) binds for the most number of intervals.
S>>NIL_SETB_KHTB1	172 (197)	*Out = Nil, avoid overloading Keith to Tailem Bend #1 132 kV line on trip of South East to Tailem Bend 275 kV line*

Constraint Equation ID (System Normal Bold)	2015 Hours (2014 Hours)	*Description* Notes
NSA_Q_GSTONE34_xxx	151 (69)	*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.
S_LB3_0	138 (46)	*Discretionary upper limit for Lake Bonney 3 generation of 0 MW* The Blanche to Mt Gambier 132 kV line was out for 1.5 days in 2015 compared to 2.3 days in 2014. See Table 6.

Figure 4 Top 10 binding constraint equations per month



3.2 Frequency Control Ancillary Service

For FCAS constraint equations, it is expected that system normal constraint equations will continue to be in the top 20 binding list unless transmission outages for significant time require 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)	2015 Hours (2014 Hours)	*Description* Notes
F_I+NIL_MG_R5	7,338 (7,678)	*NEM raise 5 minute requirement for a NEM generation event* The largest unit is usually Kogan Creek or one of the large NSW units.
F_I+NIL_MG_R6	7,102 (6,734)	*NEM raise 6 second requirement for a NEM generation event*

Constraint Equation ID (System Normal Bold)	2015 Hours (2014 Hours)	*Description* Notes
F_I+NIL_MG_R60	6,974 (6,666)	*NEM raise 60 second requirement for a NEM generation event*
F_I+NIL_APD_TL_L5	4,626 (5,723)	*NEM lower 5 min Service Requirement for the loss of APD potlines*
F_I+NIL_DYN_LREG	3,935 (4,222)	*NEM lower regulation requirement*
F_I+NIL_APD_TL_L60	3,724 (3,890)	*NEM lower 60 sec Service Requirement for the loss of APD potlines*
F_MAIN++APD_TL_L5	3,651 (1,979)	*Mainland lower 5 min Service Requirement for the loss of APD potlines, Basslink able to transfer FCAS*
F_MAIN++APD_TL_L60	3,532 (1,855)	*Mainland lower 60 sec Service Requirement for the loss of APD potlines, Basslink able to transfer FCAS*
F_MAIN++ML_L6_0400	3,386 (1,081)	*Mainland lower 6 second requirement for a mainland load event, Basslink able transfer FCAS*
F_T++RREG_0050	3,062 (1,034)	*Tasmania raise regulation requirement greater than 50 MW, Basslink able transfer FCAS*
F_T+NIL_MG_R5	2,240 (184)	*Tasmania raise 5 minute requirement for a Tasmania generation event, Basslink unable to transfer FCAS*
F_T+NIL_MG_R6	2,139 (392)	*Tasmania raise 6 second requirement for a Tasmania generation event, Basslink unable to transfer FCAS*
F_I+ML_L6_0400	1,974 (3,125)	*NEM lower 6 second requirement for a NEM load event*
F_T+NIL_MG_R60	1,920 (391)	*Tasmania raise 60 second requirement for a Tasmania generation event, Basslink unable to transfer FCAS*
F_T+NIL_WF_TG_R5	1,825 (237)	*Tasmania raise 5 minute requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS*
F_T+NIL_WF_TG_R6	1,591 (269)	*Tasmania raise 6 second requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS*
F_T+NIL_WF_TG_R60	1,485 (268)	*Tasmania raise 60 second requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS*
F_MAIN+APD_TL_L5	1,257 (696)	*Mainland lower 5 min Service Requirement for the loss of APD potlines, Basslink unable to transfer FCAS*
F_MAIN+APD_TL_L60	1,250 (693)	*Mainland lower 60 sec Service Requirement for the loss of APD potlines, Basslink unable to transfer FCAS*
F_MAIN+ML_L6_0400	1,213 (565)	*Out = Nil, lower 6 sec requirement for a Mainland load event, ML = 400, Basslink unable 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 exclude 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 cannot be attributed to a single region.

The three graphs below indicate the following trends:

- Total binding hours in 2015 were similar to the 2010 and 2014 total, but lower than the peak in 2013. South Australia had the highest number of binding hours and Tasmania the lowest.
- New South Wales binding hours in 2015 remained high (3,112 hours) but less than the 2013 total (5,095 hours) and 2014 (3,586 hours). The high number of binding hours in 2013 was due to the increase in binding hours for the New South Wales to Queensland voltage stability and Directlink constraint equations.

- Victorian binding hours were much higher in 2015 (at 5,660 hours) than the previous five years (the second highest was 3,437 hours in 2010). The high binding hours in 2015 are mainly due to:
  - An increase from 317 to 1091 hours for the transient export limit constraint equation (V::N_NIL_xxx) – see Figure 13
  - A large increase in hours of flow from Victoria to Tasmania (see Figure 12). This increased the binding hours on the main Basslink constraint equations V_T_NIL_BL1 (from 164 to 527 hours) and V_T_NIL_FCSPS (from 335 to 526 hours).
  - An increase in hours of high flows into South Australia (see Figure 14) increased the binding hours for the overload of the Heywood transformers (V>S_NIL_HYTS_HYTX) from 474 hours to 819 hours.
- The South Australian 2015 binding hours (3,383 hours) were the highest in the past five years (previous highest was 2,871 hours in 2012). This was mainly due to:
  - The transient stability limit for loss of the largest South Australian generator (V::S_NIL_MAXG_xxx) increasing from zero hours in 2014 to 243 hours in 2015.
  - An increase in binding hours (from 242 to 452 hours) for the North West Bend to Robertstown overload constraint equation (S>V_NIL_NIL_RBNW).
- The Queensland binding hours in 2015 (at 914 hours) are the lowest since the start of the NEM. The constraint equations that bound in the peak years of 2010 and 2014 bound very little in 2015. 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 (this was removed with an augmentation in Queensland in late 2013). 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. The 2014 and 2015 binding levels are the lowest in the past 5 years.
- Thermal overload constraint equations bound for 5,673 hours in 2015 – down from the 2013 peak of 6,633 hours but still the second highest since 2010.
- 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 2015, the binding hours were the highest in the past five years (at 2,532 hours) mainly due to the increase in binding hours for the Victoria to NSW and Victoria to South Australia transient limits (see dot points above).
- System-normal binding hours in 2015 were lower than 2014 (7,849 hours and 8,116 hours, respectively). This is up from the all-time low in 2012 (5,333 hours) 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 and 2015 with 5,353 and 5,748 hours.

Figure 5 Binding constraint equations by region

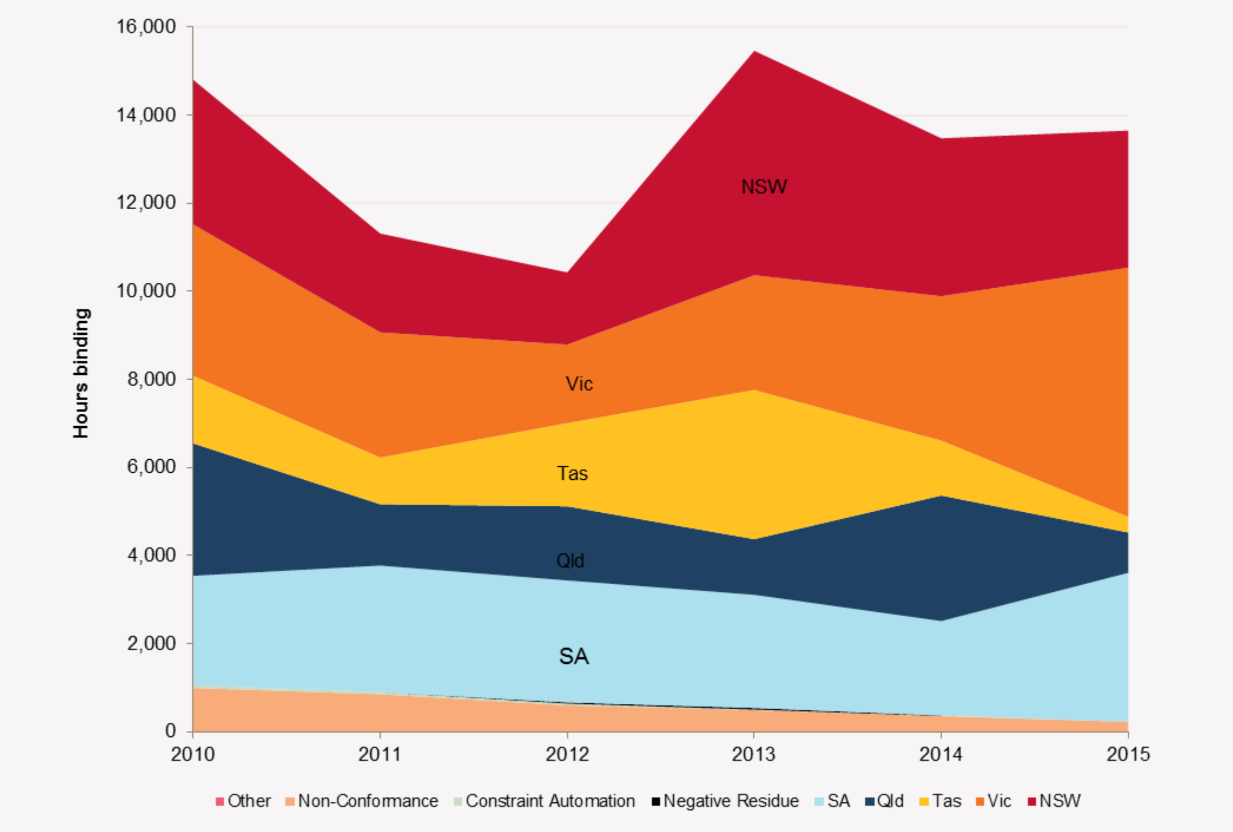


Figure 6 Binding constraint equations by limit type

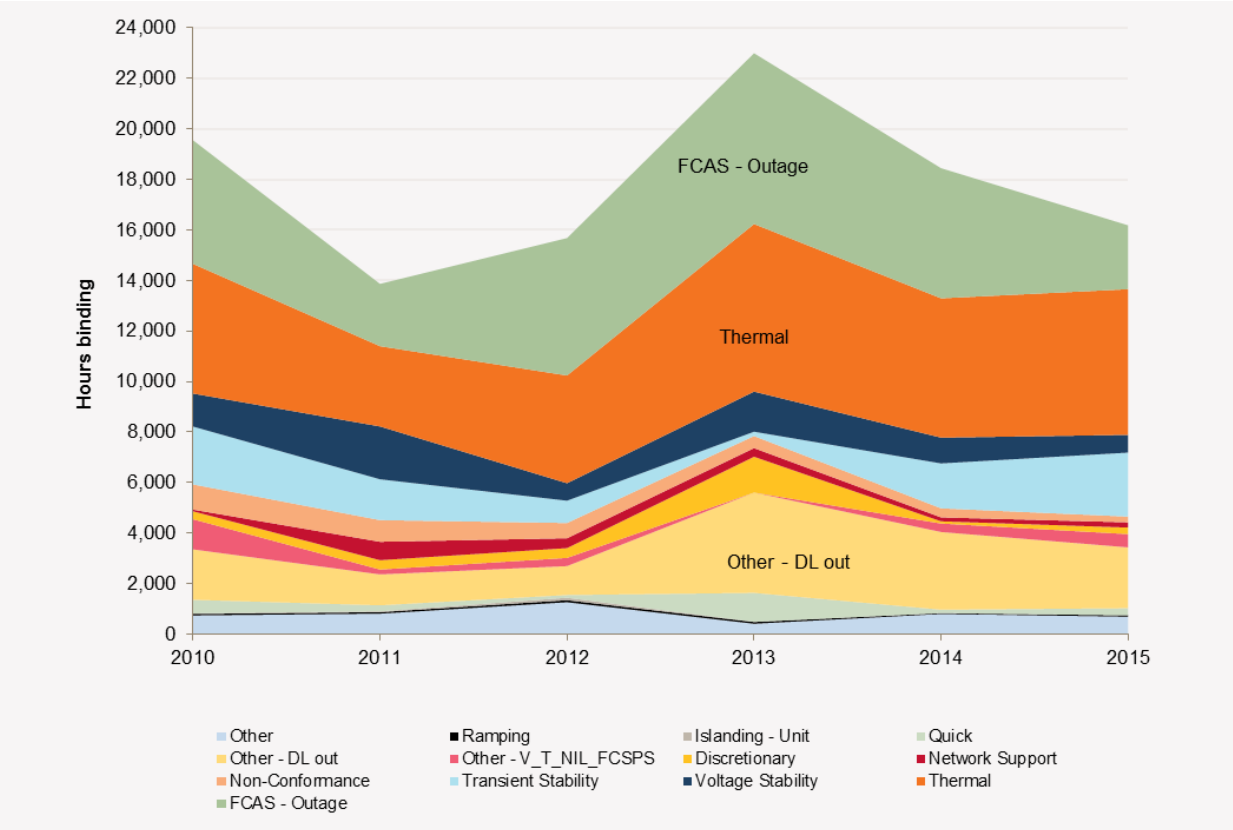
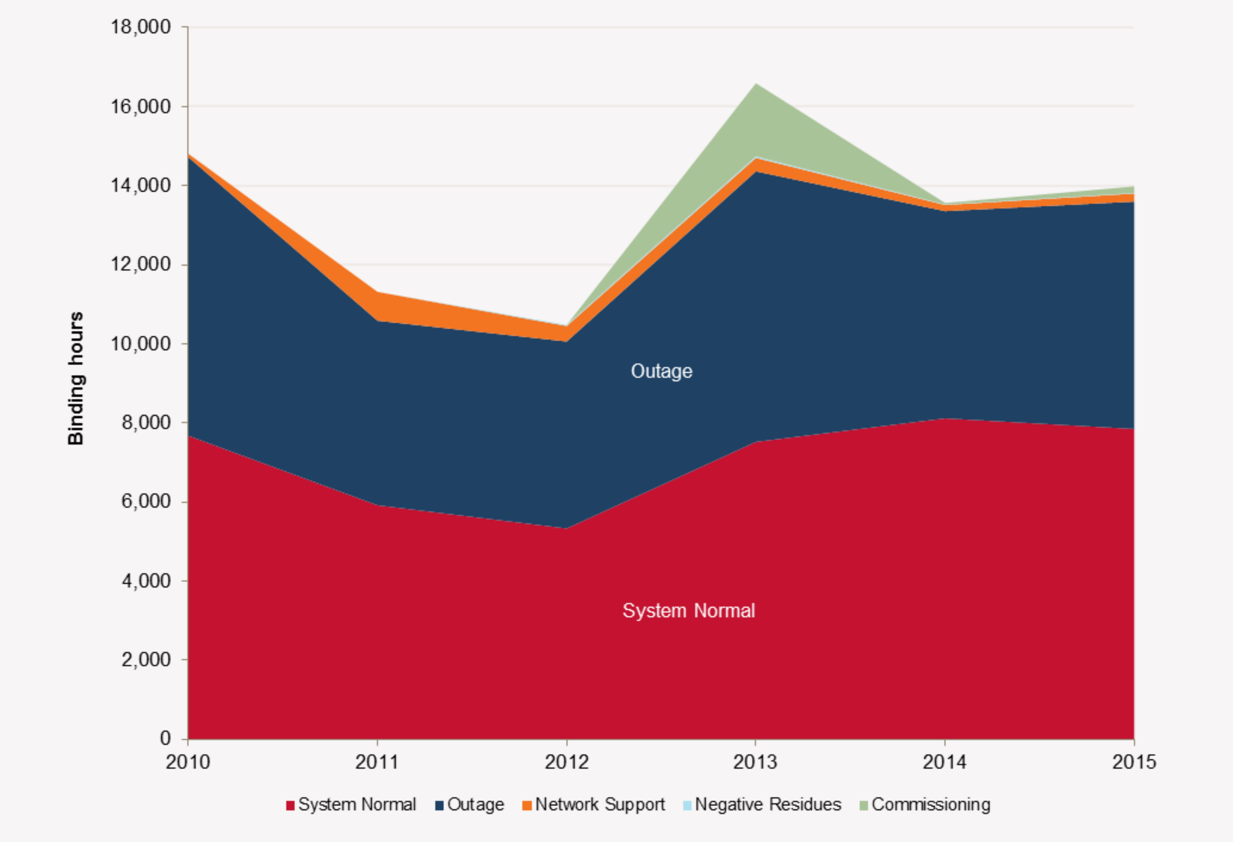


Figure 7 Binding constraint equations by category (system normal; outages)



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[8] 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 is 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 2014 values in brackets below the 2015 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

Constraint Equation ID (System Normal Bold)	2015 Market Impact (2014 Market Impact)	2015 Hours (2014 Hours)	*Description* Notes
NSA_Q_GSTONE34_xxx	$16,446,885 ($163,070)	149.7 (68.9)	*Gladstone 3 + 4 >= various levels for Network Support Agreement* See Table 3 for comments
NSA_S_PORxxx	$5,306,096 ($3,587,599)	32.3 (23.3)	*Network Support Agreement for Port Lincoln Units 1 and 2*
F_S+LREG_0035	$4,643,040 (0)	620.6 (0)	*South Australia lower regulation FCAS requirement greater than 35 MW* This constraint equation is normally invoked for a risk of islanding or an islanded South Australia
F_S+RREG_0035	$4,630,036 (0)	618.6 (0)	*South Australia raise regulation FCAS requirement greater than 35 MW* This constraint equation is normally invoked for a risk of islanding or an islanded South Australia
T>T_NIL_110_1	$1,370,198 ($1,289,227)	107.1 (104.1)	*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.
N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B	$1,101,202 ($522,292)	177.2 (72.2)	*Out = Nil, avoid voltage collapse for loss of the largest Queensland generator* See Table 3 for comments

8 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 $13,800 on 1st July 2015).

Constraint Equation ID (System Normal Bold)	2015 Market Impact (2014 Market Impact)	2015 Hours (2014 Hours)	*Description* Notes
T_MRWF_QLIM_xx	$730,553 ($1,653,083)	58.5 (133.3)	*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.
S_LB3_0	$517,724 ($60,541)	137.5 (45.6)	*Discretionary upper limit for Lake Bonney 3 generation of 0 MW* See Table 3 for comments
V>S_NIL_HYTX_HYTX	$400,941 ($159,592)	818.1 (473.8)	*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
NSA_V_BDL0xxx	$363,365 ($353,989)	7.3 (5.3)	*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.
N_X_MBTE_3A & N_X_MBTE_3B	$341,591 ($209,639)	1,311.2 (1,661.8)	*Out = all three Directlink cables* See Table 3 for comments
F_T+NIL_WF_TG_R6	$306,329 ($50,940)	1,590.3 (269.0)	*Tasmania raise 6 second requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS* See Table 4 for comments
Q>NIL_MRTA_B	$300,622 ($68,514)	19.6 (2.6)	*Out = Nil, avoid overloading Middle Ridge to Tangkam (732) 110 kV line on no contingencies*
N>>N-NIL__3_OPENED	$298,577 ($441,872)	26.2 (4.6)	*Out = Nil, avoid overloading Liddell to Muswellbrook (83) 330kV line on trip of Liddell to Tamworth (84) 330 kV line*
Q_RS_260	$275,275 (0)	1.7 (0)	*Ross cut-set discretionary upper limit of 260 MW*
S>V_NIL_NIL_RBNW	$270,134 ($2,478,435)	451.3 (239.8)	*Out = Nil, avoid overloading the North West Bend to Robertstown 132 kV line on no line trips* See Table 3 for comments
Q_FNQ_220	$252,130 (0)	1.6 (0)	*Far North Queensland discretionary upper transfer limit of 220MW*
S>XKHTB1+2_SETX_SETX	$247,093 (0)	25.0 (0)	*Out = both Keith to Tailem Bend 132 kV, avoid overloading a South East 275/132 kV transformer on trip of the other South East 275/132 kV transformer*
N_X_MBTE2_A & N_X_MBTE2_B	$228,731 ($116,128)	1,036.1 (579.0)	*Out = two Directlink cables* See Table 3 for comments
Q>NIL_BI_FB	$223,253 ($212,282)	258.8 (1,062.7)	*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*

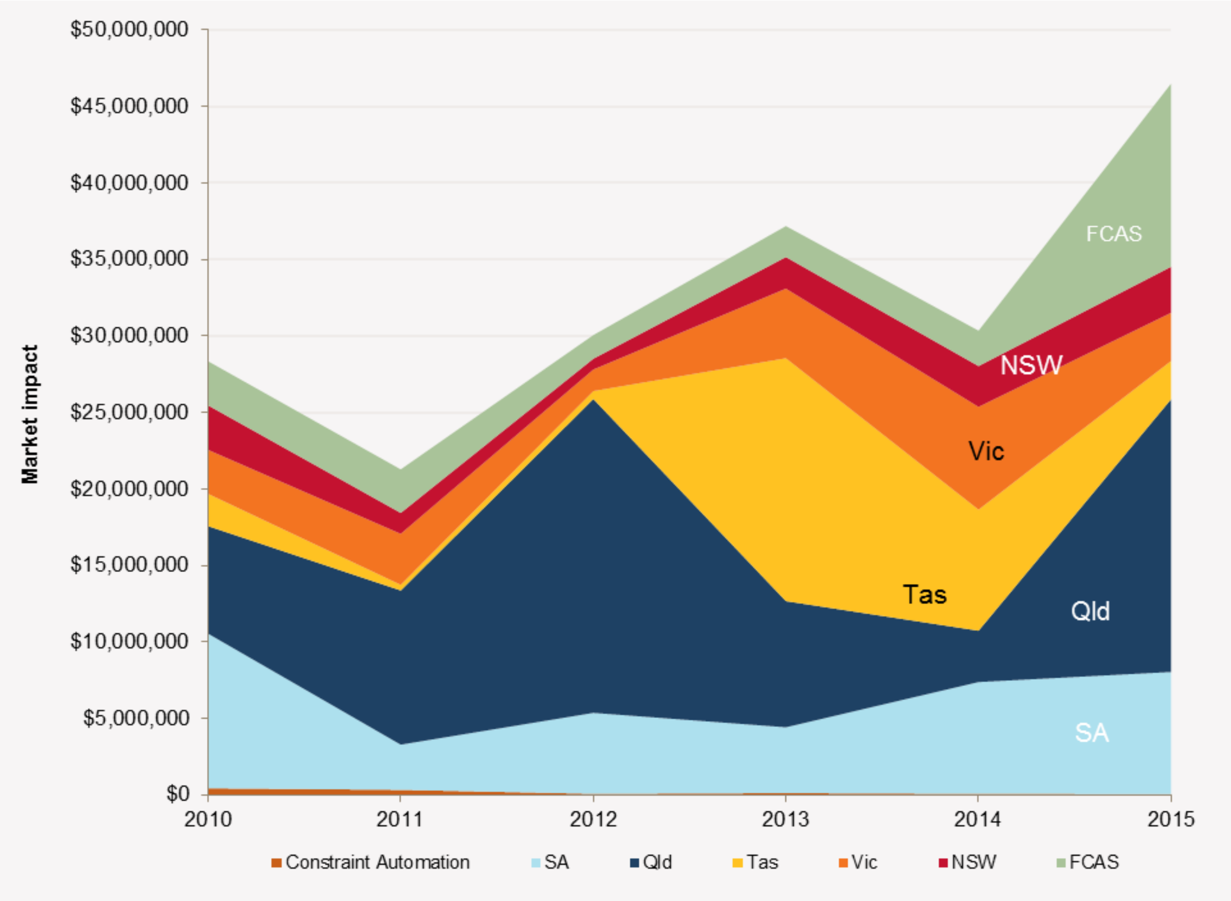
4.1 Market Impact Trends

The market impact has increased in the past five years[9] with the exception of 2014 (see Figure 8). Most regions have a normal amount of market impact per year and the increases are spikes in particular regions. In 2012 there was a spike in Queensland which was mainly

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

due to network support agreements. In 2013 the spike was in Tasmania, mainly due to the Musselroe Wind Farm commissioning. In 2015 there was a spike in Queensland, again due to network support agreements. Also in 2015 there was a spike in FCAS costs which were due to outages between South Australia and Victoria.

Figure 8 Market impact by region



From 2010 to 2015, with the exception of 2014, the market impact of system normal constraint equations and outage constraint equations increased (see Figure 9).

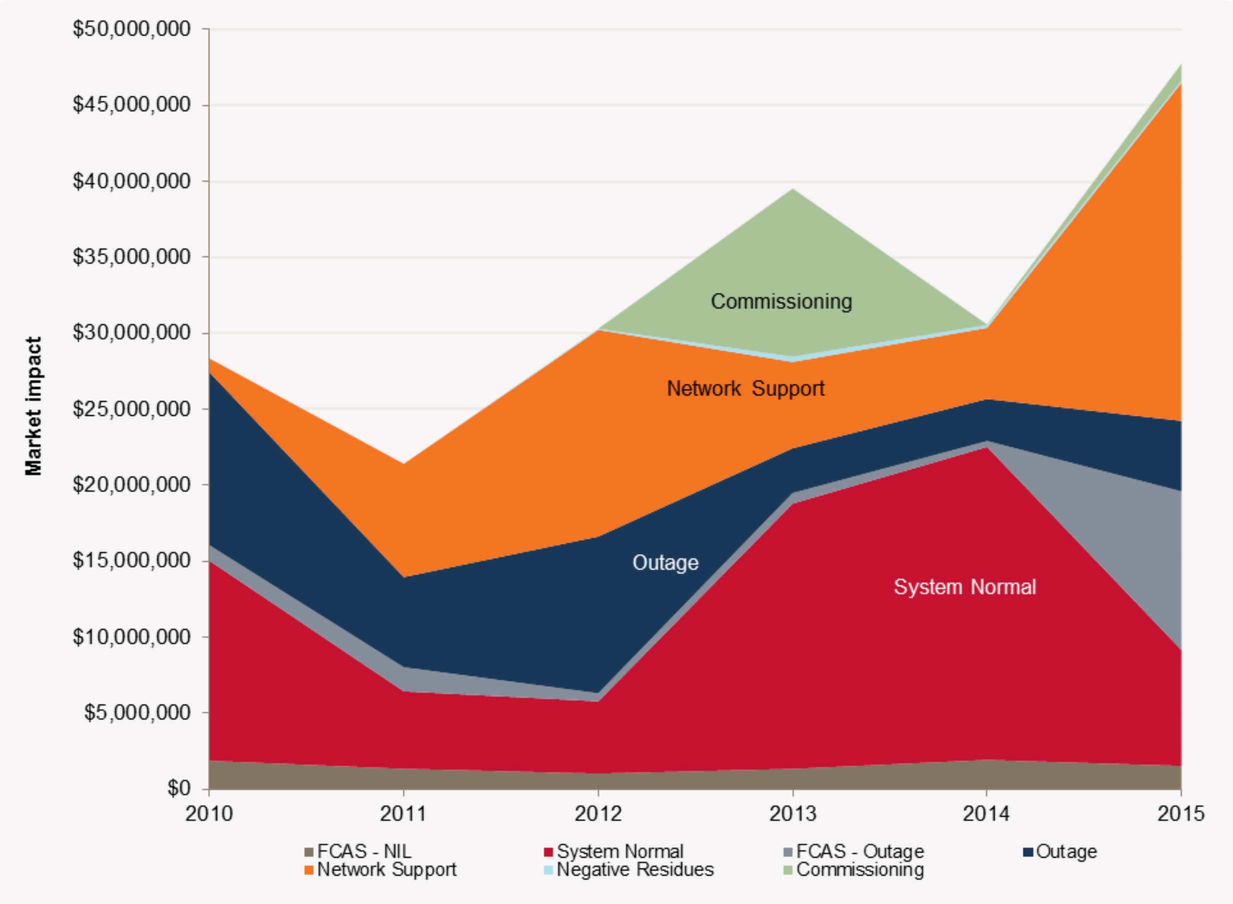
In 2012, network support and outages increased, while system normal slightly decreased. The network support increase was due to network support agreements in Queensland and South Australia.

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 constraint equations on Tamar Valley generation in Tasmania and Robertstown – North West Best 132 kV line in South Australia.

In 2015 the market impact increased again. This was mainly due to an increase due in network support agreements in Queensland and South Australia and FCAS for outages between South Australia and Victoria (a total impact of $9.3 million). System normal decreased mainly due to Tamar Valley not generating, removal of the Tarong transformer constraint equation (due to commissioning of the Coolumboola 275 kV) and lower binding hours on the Robertstown – North West Best 132 kV line.

Figure 9 Market impact for system normal and outages



5. CONSTRAINT EQUATIONS SETTING INTERCONNECTOR LIMITS

This chapter examines each NEM interconnector and the binding constraint equations that most often set the limits on that interconnector.[10]

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 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, 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 direct current (DC) link between Terranora and Mullumbimby. The three separate DC cables that 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.

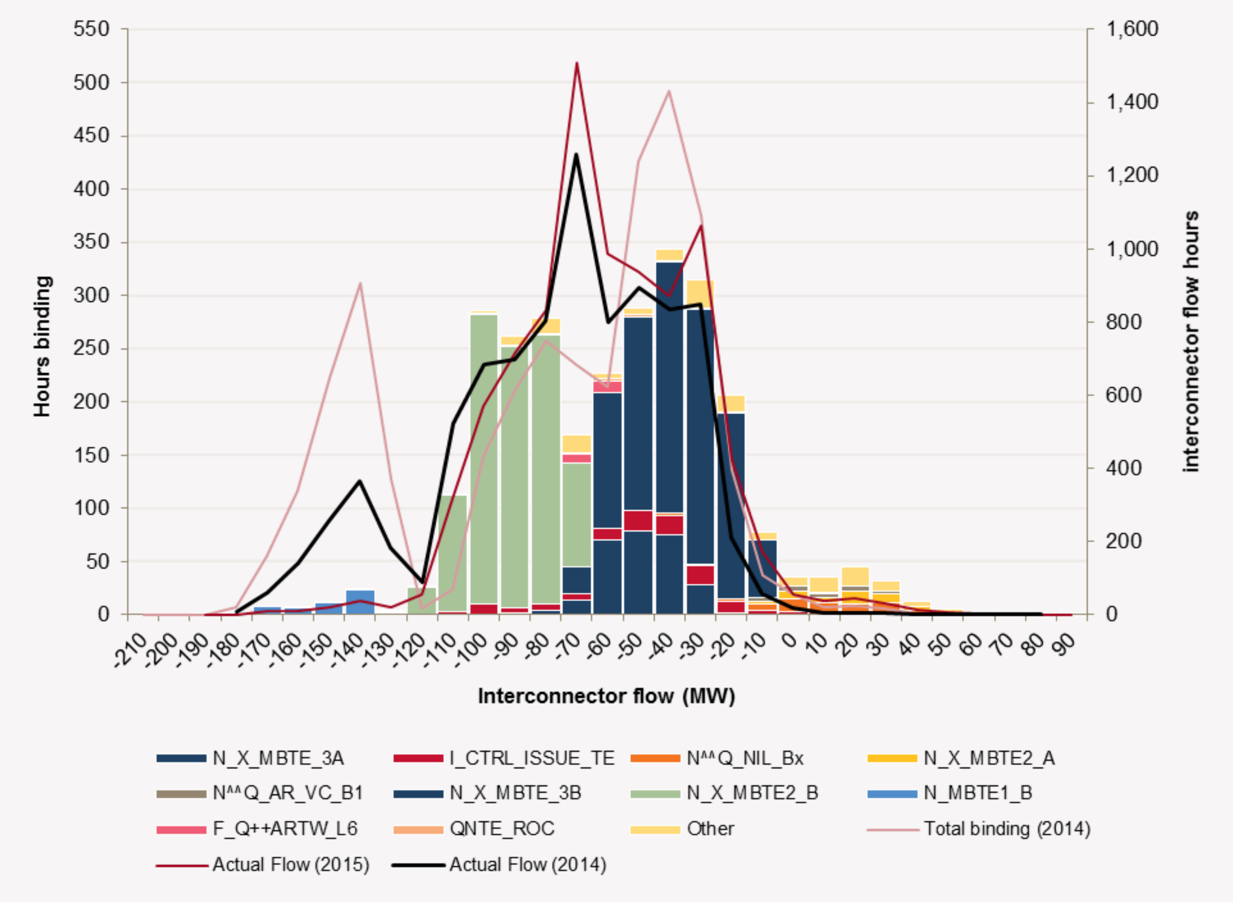
Most of this interconnector's flows are towards New South Wales, so both the import and export values are negative (unlike the other NEM interconnectors). It is usually constrained by thermal limits in northern New South Wales (N>N-NIL_LSDU) or by the rate of change on Directlink (NQTE_ROC, QNTE_ROC).

The Terranora interconnector normally appears 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).

Similar to 2014, most of the time that Terranora was restricted in 2015 was due to the outage of all three Directlink cables or outages of a single Directlink cable (see Figure 10).

[10] AEMO. *Interconnector Capabilities*. Available at: http://www.aemo.com.au/Electricity/Resources/Reports-and-Documents/Network-Operations/Interconnector-Capabilities. Viewed: 2 March 2016.

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



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

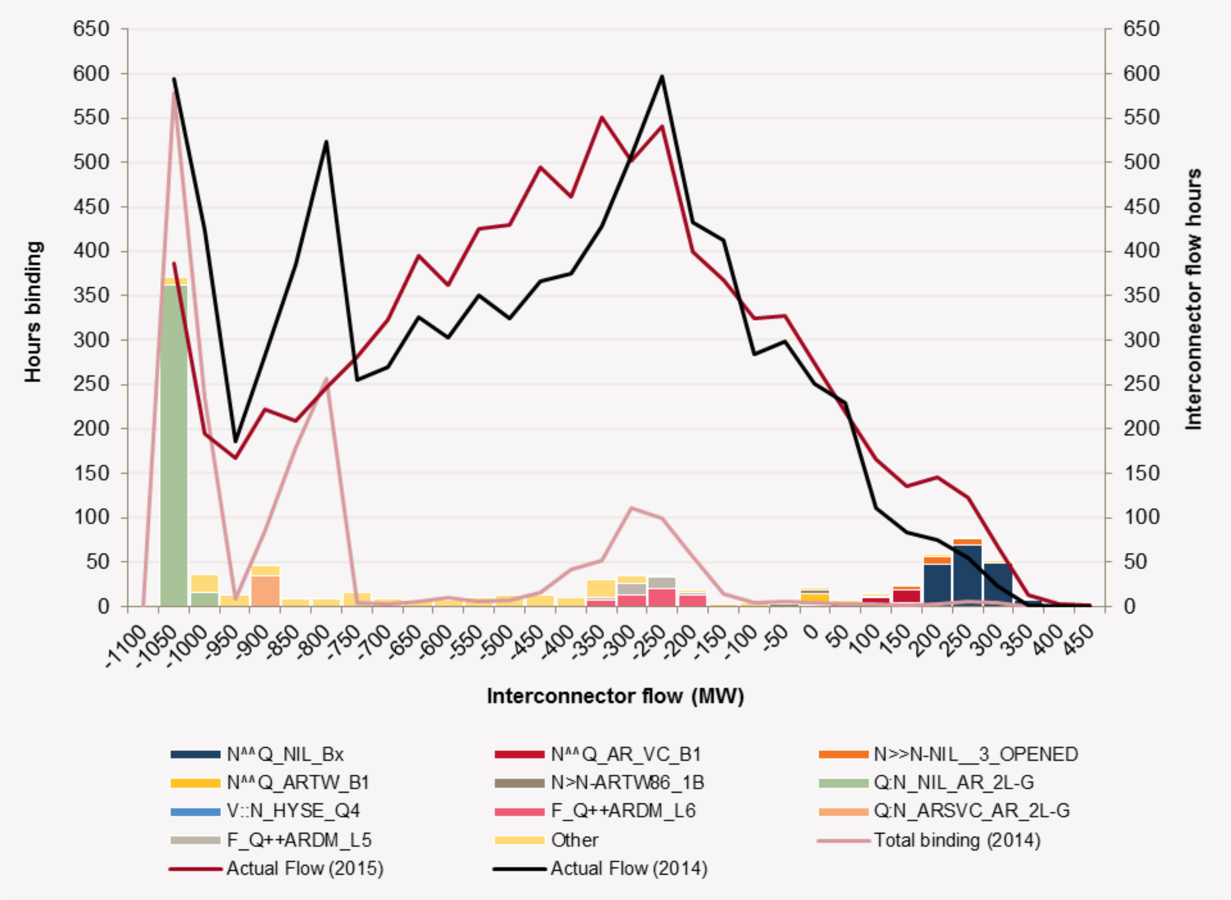
The Queensland to New South Wales interconnector (QNI) is a 330 kV alternating current (AC) interconnection between Dumaresq in New South Wales and Bulli Creek in Queensland. It was commissioned in 2001 as a double-circuit 330 kV line between Armidale and Braemar, and a double-circuit 275 kV line between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

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.

Historically, most flows are greater than 500 MW from Queensland into New South Wales. In 2014 and 2015, the flows were mainly from Queensland to New South Wales, albeit at lower values between 200 and 350 MW into New South Wales (see Figure 11). The most constrained flows were between 1,000 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 can transfer FCAS between Victoria and Tasmania. Along with the other interconnections to Victoria (VIC1-NSW1, V-SA and Murraylink), Basslink appears in many Victorian constraint equations. This can lead to situations where many or all of these interconnectors can be limited due to the same network limitation.

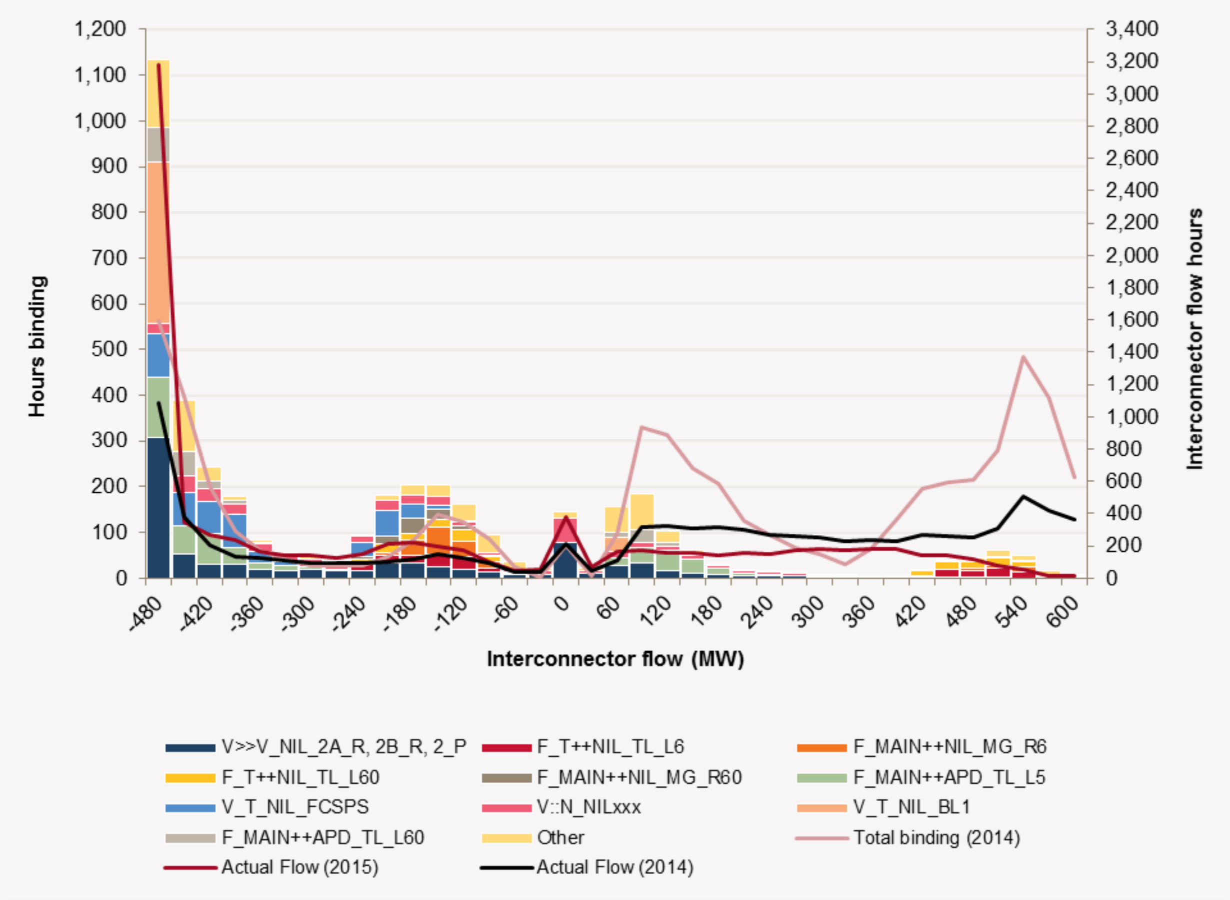
Most limitations on Basslink transfers are due to FCAS constraint equations for both mainland and Tasmanian contingency events.

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 yearsmost flows and binding hours on Basslink were from Tasmania to Victoria. In 2014 and 2015, this reversed with nearly 1,100 hours of flows of 480 MW into Tasmania. There were very few binding hours from Tasmania to Victoria (see Figure 12) in 2015.

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.

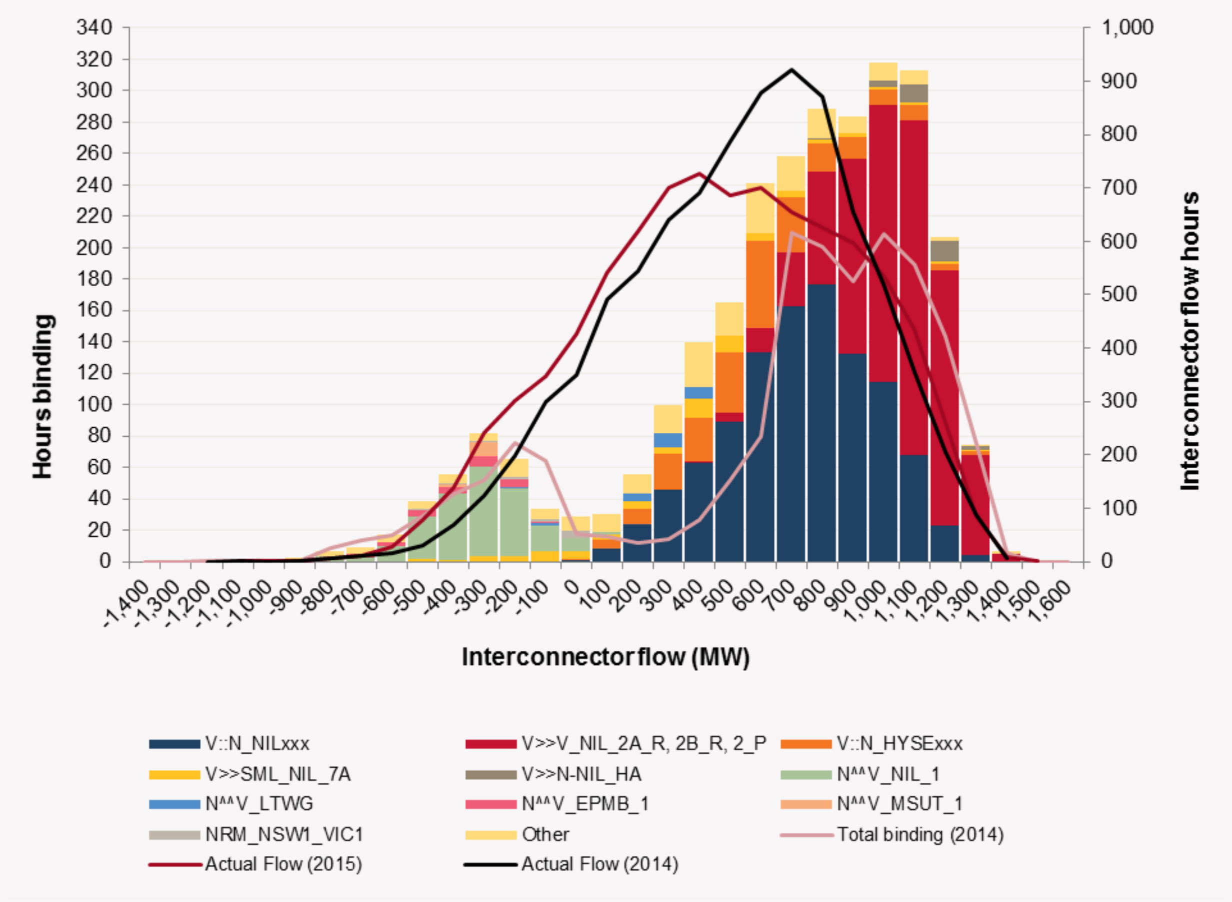
VIC1–NSW1 can bind in either direction for high demand in New South Wales or Victoria. Transfer from Victoria to New South Wales is mainly limited by the thermal overload limits on the South Morang F2 transformer (V>>V_NIL_2A_R and V>>V_NIL_2B_R and V>>V_NIL_2_P), the South Morang to Dederang 330 kV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

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 thermal overload limits on the Murray to Dederang 330 kV lines (V>>V_NIL_1B).

In 2014 and 2015, the hours at each flow level and the binding hours on VIC1–NSW1 were similar. The main difference in 2015 (from 2014) was that the high flow levels into New South Wales were constrained for more 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.

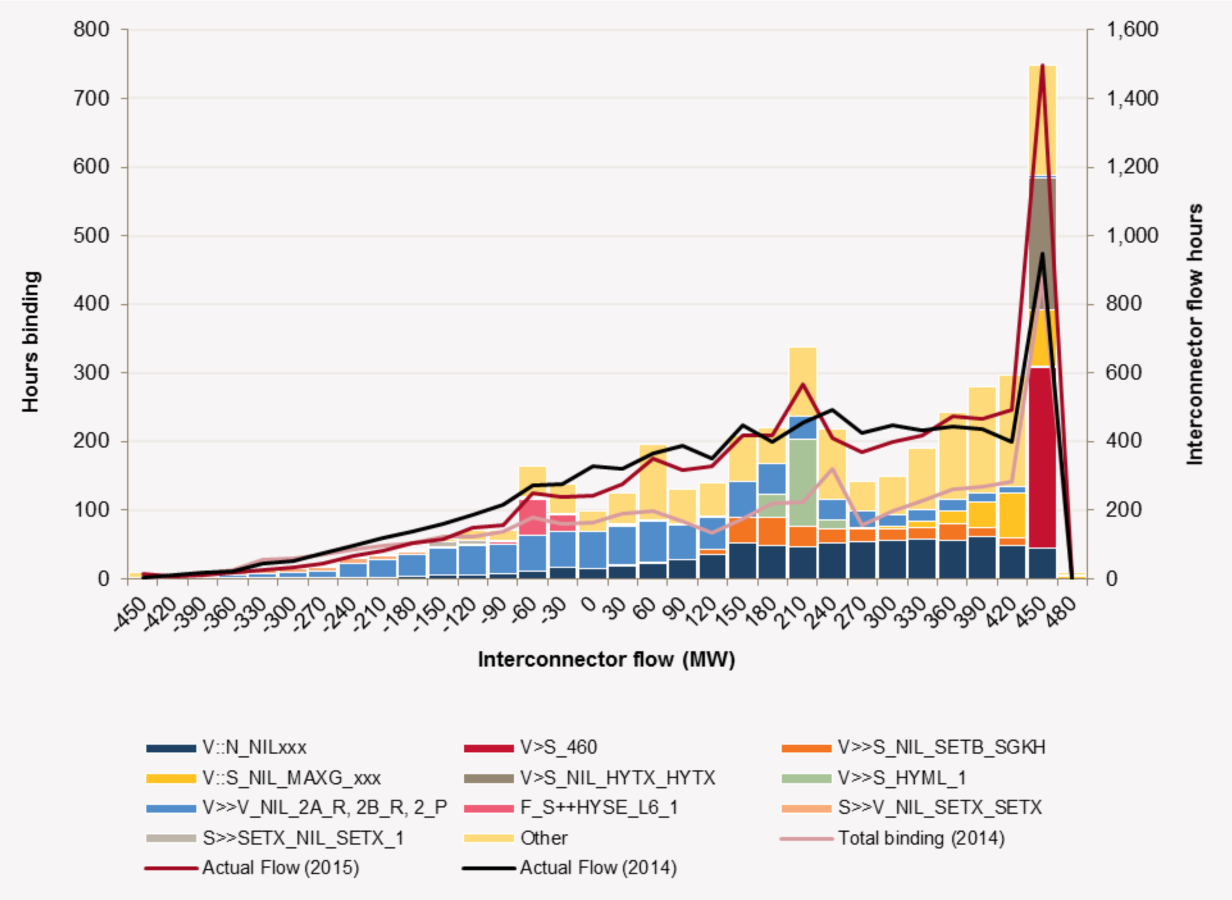
The Heywood interconnector is being upgraded in stages in 2015 and 2016. In December 2015 the third 500/275 kV transformer at Heywood was commissioned and the limit increased to 500 MW.

Flows are now most often restricted by thermal overloads on the Snuggery to Keith 132 kV line (V>>S_NIL_SETB_SGKH), transient stability limit for loss of the largest South Australian generator (V::S_NIL_MAXG_xxx) and, until December 2015, the Heywood 500/275 kV transformers (V>S_460 and V>S_NIL_HYTX_HYTX). The Heywood transformer constraint equations were removed with commissioning of the third Heywood transformer.

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 2014 and 2015 with the exception of more hours for high flows into South Australia (at the 450 MW flow level). There was also a corresponding increase in the binding hours at the 450 MW flow level compared to those of 2014. 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).

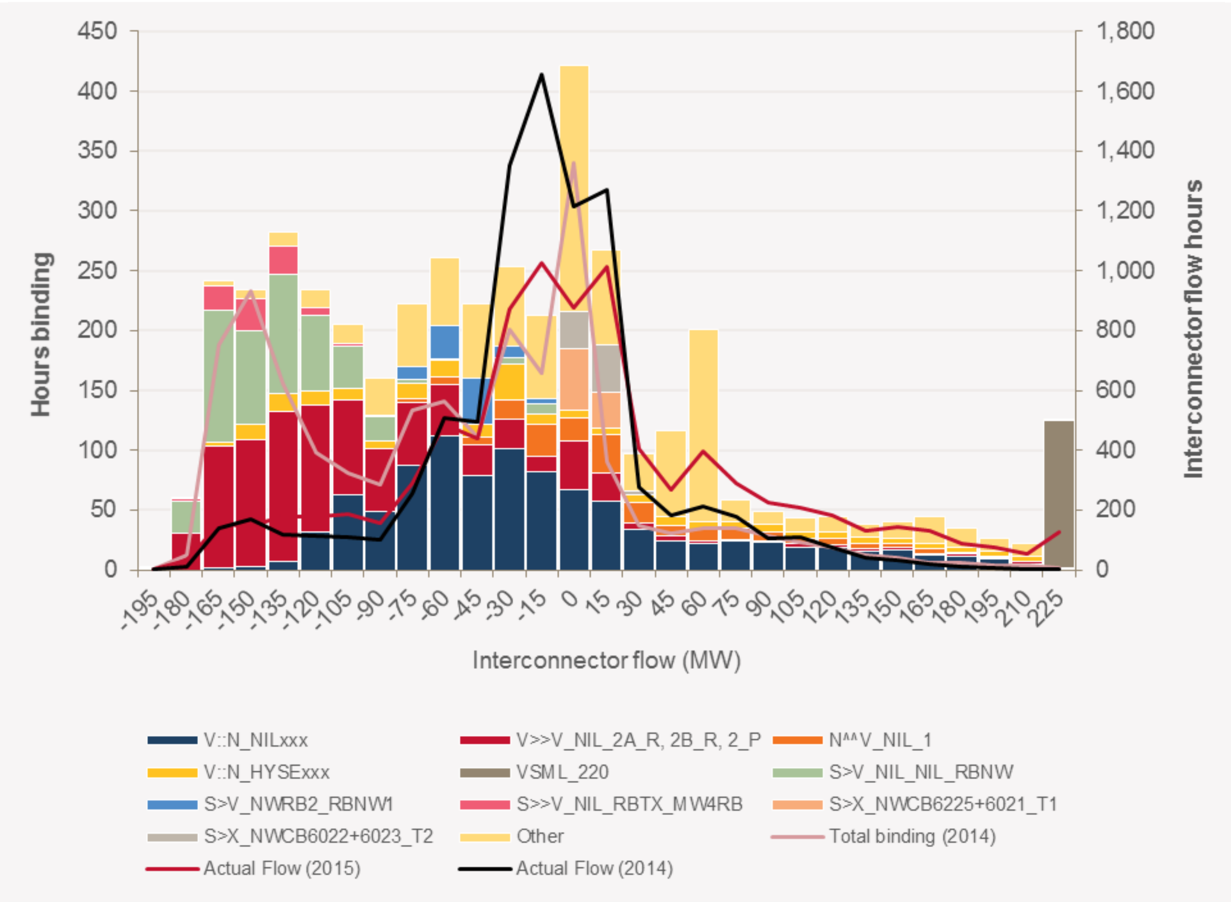
Or they can be limited by the voltage collapse limit for loss of the Darlington Point to Buronga (X5) 220 kV line for an outage of the NSW Murraylink runback scheme (V^SML_NSWRB_2).[11]

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).

In 2015 and 2014, the number of hours at each flow level on Murraylink was very similar. The main difference in 2015 was a decrease at higher flows into Victoria, and an increase in binding hours at 0 MW. This is shown in Figure 15.

Figure 15 Binding constraint equation distribution for Murraylink



[11] 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 2015, and compares outage submission and start times for each TNSP.

6.1 Major outages

Table 6 shows the duration of 2015 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	2015 Days (2014 Days)	Outage Notes
N-MBTE_1	359.8 (365.0)	*One Directlink cable*
N-X_MBTE_2	251.4 (169.8)	*Two Directlink cables*
N-AR_VC1	59.1 (9.9)	*Armidale SVC*
N-X_MBTE_3	55.1 (70.3)	*All three Directlink cables*
V-HYTX	30.1 (4.6)	*One Heywood 500/275 kV (M1 or M2) transformer*
I-HYSE	28.3 (4.9)	*One Heywood to South East 275 kV line*
V-EPMB	20.5 (3.3)	*One Eildon to Mt Beauty 220 kV line*
S-NWRB2	18.5 (0.3)	*North West Bend to Robertstown No.2 132 kV line*
F-I_ML_APD	15.0 (38.2)	*Out=Nil, Dymanic FCAS for APD Load Event*
S-X_KHTB1+2	14.3 (0)	*Both Keith to Tailem Bend 132 kV lines*
S-PWSE	10.6 (0)	*Penola West to South East 132 kV line*
S-NWCB6021+6225	8.3 (0)	*North West Bend CBs 6021 and 6225*
S-NWCB6022+6023	7.2 (0)	*North West Bend 132 kV circuit breakers 6022 and 6023. This also opens the North West Bend to Monash #2 132 kV line*
I-ML_ZERO	6.6 (10.0)	*Limit Murraylink to zero in either direction*
V-HOWA	5.4 (0)	*Horsham to Waubra 220 kV line*
I-CTRL_ISSUE_TE	4.9 (0.9)	*DC Link Control Issue Constraint for Terranora*
N-CNUT_01	4.6 (0.8)	*Canberra to Upper Tumut (01) 330 kV line*
V-KTTX_A3_R	3.9 (7.4)	*Keilor 500/220 kV (A3) transformer, Victorian radial mode*
S-KHSG	3.8 (0)	*Keith to Snuggery 132 kV line*
I-VS_050	3.8 (0)	*Victoria to SA on VicSA upper transfer limit of 50 MW*
N-ARTW_86	3.5 (1.6)	*Armidale to Tamworth (86) 330 kV line*
F-N-ARDM_ONE	3.5 (2.2)	*One Armidale to Dumaresq (8C or 8E) 330 kV line*
N-LTWG_RADIAL	2.9 (0.8)	*Lower Tumut to Wagga line*
V-HWSM	2.9 (7.2)	*Hazelwood to South Morang 500 kV line*
V-MLMO	2.5 (1.0)	*Moorabool to Mortlake 500 kV line*
I-MSUT	2.2 (16.7)	*Murray to Upper Tumut (65) 330 kV line*
S-TBSE	2.2 (0)	*One South East to Tailem Bend 275 kV line*
V-BEKG	2.0 (6.6)	*Bendigo to Kerang 220 kV line*
V-HYMO	1.9 (0.3)	*Heywood to Mortlake No.2 500 kV line*
N-LDTW_84	1.7 (2.5)	*Liddell to Tamworth (84) 330 kV line*
S-BNMT	1.5 (2.3)	*Blanche to Mt Gambier 132 kV line*
Q-FNQ_220	1.4 (0)	*Qld FNQ upper transfer limit of 220MW (discretionary)*
V-BAWA	1.2 (0)	*Ballarat to Waubra 220 kV line*
V-HYTR	1.0 (0.8)	*Heywood to Tarrone 500 kV line*

Constraint Set ID	2015 Days (2014 Days)	Outage Notes
S-BNSG	0.9 (0)	*Blanche to Snuggery 132 kV line*
F-I-BCDM_ONE	0.9 (9.8)	*One Bulli Creek to Dumaresq 330 kV line - FCAS Requirements*
N-ARTW_85	0.8 (3.4)	*Armidale to Tamworth (85) 330 kV line*
S-SESG	0.8 (0)	*South East to Snuggery 132 kV line*
V-DDMS	0.8 (1.6)	*One Dederang to Murray (67 or 68) 330 kV line*
S-X_CGTB+TB35+36	0.7 (0)	*Cherry Gardens to Tailem Bend 275 kV line and Tailem Bend 275 kV circuit breakers 6536 and 6535*

6.2 Trends for submit times

Figure 16 shows the trends relating to the 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.

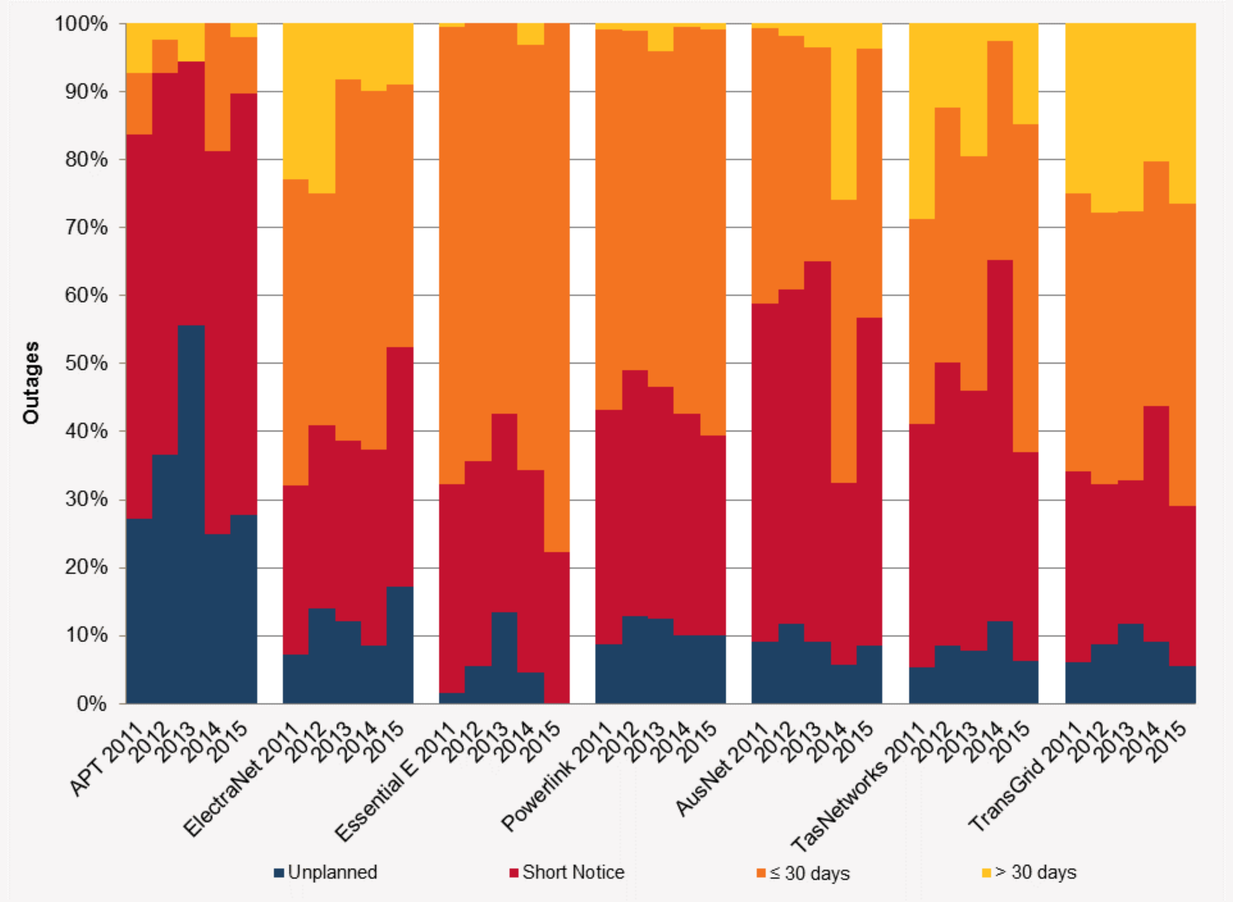
Outages previously submitted and then rescheduled for a new time are recorded as new outages in the NOS. Outages for multiple items of related plant submitted in a single entry are only counted as a single outage.

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 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 Network Service Providers (NSPs), less than 13% of outages are unplanned. Most outages are either short notice or within 30 days.
- Compared to other Tranmission Network Service Providers (TNSPs), TransGrid submits a higher percentage of their outages 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 13-month outage plans are submitted as spreadsheets and not via the Network Outage System (NOS) so 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.