Monthly Constraint Report

June 2019

A report for the National Electricity Market

Important notice

PURPOSE

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

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1. Introduction

This report details constraint equation performance and transmission congestion related issues for June 2019. Included are investigations of violating constraint equations, usage of the constraint automation and performance of Pre-dispatch constraint equations. Transmission and generation changes are also detailed along with the number of constraint equation changes.

2. Constraint Equation Performance

2.1 Top 10 binding constraint equations

A constraint equation is binding when the power system flows managed by it have reached the applicable thermal or stability limit or the constraint equation is setting a Frequency Control Ancillary Service (FCAS) requirement. Normally there is one constraint equation setting the FCAS requirement for each of the eight services at any time. This leads to many more hours of binding for FCAS constraint equations - as such these have been excluded from the following table.

Table 1 Top 10 binding network constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	2291 (190.91)	15/05/2019
Q>>WOPW_WOSP_WOGP_2	Out= Woolooga to Palmwoods (810) 275kV line, avoid O/L Woolooga to Gympie (748/2) 132kV line on trip of Woolooga to South Pine (807) 275kV line, Feedback	1459 (121.58)	29/05/2019
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	844 (70.33)	19/06/2019
V_KIATAWF_FLT_0	Limit Kiata Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	715 (59.58)	13/02/2019
S_HALWF2_0	Discretionary upper limit for Hallett 2 Wind Farm generation of 0 MW	694 (57.83)	7/08/2018
Q>NIL_BI_CAGS_CALV_O	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV split between T022 Callide A and H015 Lilyvale.	615 (51.25)	11/01/2019
Q^^NIL_QNI_SRAR	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	502 (41.83)	18/06/2019
S_HALWF_0	Discretionary upper limit for Hallett Wind Farm generation of 0 MW	400 (33.33)	7/08/2018

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
S_DVRB2_270	Out = DV-LK 275kV line Or CN-RB 275kV line O/S, discretionary upper limit for Hornsdale WF1+ Hornsdale WF2+Hornsdale WF3+Hallet Hill GT + Hornsdale battery (i.e. generation + load component) <= 270 MW	392 (32.66)	8/11/2017
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	367 (30.58)	15/05/2019

2.2 Top 10 binding impact constraint equations

Binding constraint equations affect electricity market pricing. The binding impact is used to distinguish the severity of different binding constraint equations.

The binding impact of a constraint is derived by summarising the marginal value for each dispatch interval (DI) from the marginal constraint cost (MCC) re-run[1] over the period considered. The marginal value is a mathematical term for the binding impact arising from relaxing the RHS of a binding constraint by one MW. As the market clears each DI, the binding impact is measured in $/MW/DI.

The binding impact in $/MW/DI is a relative comparison and a helpful way to analyse congestion issues. It can be converted to $/MWh by dividing the binding 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 2 Top 10 binding impact network constraint equations

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Change Date
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	875,405	19/06/2019
S_HALWF2_0	Discretionary upper limit for Hallett 2 Wind Farm generation of 0 MW	772,894	7/08/2018
S_HALWF_0	Discretionary upper limit for Hallett Wind Farm generation of 0 MW	436,882	7/08/2018
N_MOREESF1_ZERO	Moree Solar Farm upper limit of 0 MW	408,002	18/12/2015
Q>>WOPW_WOSP_WOGP_2	Out= Woolooga to Palmwoods (810) 275kV line, avoid O/L Woolooga to Gympie (748/2) 132kV line on trip of Woolooga to South Pine (807) 275kV line, Feedback	353,410	29/05/2019
F_MAIN+NIL_DYN_RREG	Mainland Raise Regulation Requirement, Feedback in Dispatch, increase by 60 MW for each 1s of time error below -1.5s	302,108	23/05/2019
V_BANSF_22INV	Limit Bannerton Solar Farm upper limit to 0 MW if number of inverter available exceed 22. Constraint swamp out if number of inverter available not exceed 22. This is to manage voltage oscillation. DS only	195,709	27/05/2019
F_I+LREG_0210	NEM Lower Regulation Requirement greater than 210 MW	141,724	16/05/2019
V_MTMERCER_ZERO	Mt Mercer Windfarm upper limit of 0 MW	131,383	22/10/2013

1 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 is increased annually on 1st July.

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Change Date
Q>NIL_BI_CAGS_CALV_O	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV split between T022 Callide A and H015 Lilyvale.	110,942	11/01/2019

2.3 Top 10 violating constraint equations

A constraint equation is violating when NEMDE is unable to dispatch the entities on the left-hand side (LHS) so the summated LHS value is less than or equal to, or greater than or equal to, the right-hand side (RHS) value (depending on the mathematical operator selected for the constraint equation). The following table includes the FCAS constraint equations. Reasons for the violations are covered in 2.3.1.

Table 3 Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
Q>NIL_BI_CAGS_CALV_O	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV split between T022 Callide A and H015 Lilyvale.	5 (0.41)	11/01/2019
NSA_Q_BARCALDN	Network Support Agreement for Barcaldine GT to meet local islanded demand for the planned outage of 7153 T71 Clermont to H15 Lilyvale or 7154 T72 Barcaldine to T71 Clermont 132kV line	4 (0.33)	6/05/2015
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	3 (0.25)	29/01/2015
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	3 (0.25)	30/04/2018
F_T+NIL_MG_R5	Out = Nil, Raise 5 min requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	2 (0.16)	12/04/2016
F_T+NIL_MG_RECL_R5	Out = Nil, Raise 5 min requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	2 (0.16)	2/12/2016
S>LFTI_PPPW_LFTX4	Out= Torrens Island-Lefevre 275kV line (with TIPS 66kV East and West buses tied, with all 66kV feeders in western 66kV network I/S), avoid O/L LeFevre 275/132kV TX4 on trip of Pelican Point-Parafield Gardens West 275kV line, Feedback	2 (0.16)	17/03/2019
Q>NIL_BI_CAGS_CALV_C	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV intact between T022 Callide A and H015 Lilyvale.	2 (0.16)	11/01/2019
S>LFTI_PPPW_NOTI4	Out= Torrens Island-Lefevre 275kV line (with TIPS 66kV East and West buses tied, with all 66kV feeders in western 66kV network I/S), avoid O/L New Osborne-TIPS #4 66kV line, on trip of Pelican Point-Parafield Gardens West 275kV line, Feedback	2 (0.16)	18/03/2019
NC_V_JLB02	Non Conformance Constraint for Jeeralang B - 02 Power Station	2 (0.16)	21/08/2013

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
Q>NIL_BI_CAGS_CALV_O	Constraint equation violated for 5 DIs. Max violation of 7.26 MW occurred on 03/06/2019 at 0720hrs. Constraint equation violated due to Gladstone units 3 and 4 being limited by their ramp-down rates.
NSA_Q_BARCALDN	Constraint equation violated for 4 DIs. Max violation of 15 MW occurred on 26/06/2019 at 1635hrs and 27/06/2019 at 1605hrs. Constraint equation violated due to Barcaldine GT unit being limited by its start-up profile.
F_T+RREG_0050	Constraint equation violated for 2 DIs. Max violation of 45.13 MW occurred on 02/06/2019 at 1125hrs. Constraint equation violated due to Tasmania raise regulation service availability being less than the requirement.
F_T_NIL_MINP_R6	Constraint equation violated for 2 DIs. Max violation of 10.8 MW occurred on 02/06/2019 at 1125hrs. Constraint equation violated due to Tasmania raise 6 seconds service availability being less than the requirement.
F_T+NIL_MG_R5	Constraint equation violated for 2 DIs. Max violation of 43.12 MW occurred on 02/06/2019 at 1125hrs. Constraint equation violated due to Tasmania raise 5 minutes service availability being less than the requirement.
F_T+NIL_MG_RECL_R5	Constraint equation violated for 2 DIs. Max violation of 42.94 MW occurred on 02/06/2019 at 1125hrs. Constraint equation violated due to the same reason as F_T+NIL_MG_R5.
S>LFTI_PPPW_LFTX4	Constraint equation violated for 2 DIs. Max violation of 23.9 MW occurred on 16/06/2019 at 0815hrs. Constraint equation violated due to Pelican Point CCGT being trapped in its FCAS trapezium.
Q>NIL_BI_CAGS_CALV_C	Constraint equation violated for 2 DIs. Max violation of 3.08 MW occurred on 27/06/2019 at 1715hrs. Constraint equation violated due to the same reason as Q>NIL_BI_CAGS_CALV_O.
S>LFTI_PPPW_NOTI4	Constraint equation violated for 2 DIs. Max violation of 2.8 MW occurred on 16/06/2019 at 0815hrs. Constraint equation violated due to the same reason as S>LFTI_PPPW_LFTX4.
NC_V_JLB02	Constraint equation violated for 2 DIs on 08/06/2019 from 0925hrs to 0930hrs with a violation degree of 0.2 MW for each DI. Constraint equation violated due to Jeeralang B GT unit 2 being unavailable.

2.4 Top 10 binding interconnector limit setters

Binding constraint equations can set the interconnector limits for each of the interconnectors on the constraint equation left-hand side (LHS). Table 5 lists the top (by binding hours) interconnector limit setters for all the interconnectors in the NEM and for each direction on that interconnector.

Table 5 Top 10 binding interconnector limit setters

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	2291 (190.92)	-190.51 (-1015.7)
Q>>WOPW_WOSP_WOGP_2	NSW1-QLD1 Export	Out= Woolooga to Palmwoods (810) 275kV line, avoid O/L Woolooga to Gympie (748/2) 132kV line on trip of Woolooga to South Pine (807) 275kV line, Feedback	1438 (119.83)	-671.15 (108.53)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1376 (114.67)	147.82 (478.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
F_MAIN++APD_TL_L5	T-V-MNSP1 Import	Out = Nil, Lower 5 min Service Requirement for a Mainland Network Event- loss of APD potlines due to undervoltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS	615 (51.25)	66.57 (-458.5)
Q^^NIL_QNI_SRAR	NSW1-QLD1 Import	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	502 (41.83)	-904.67 (-1026.39)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	445 (37.08)	51.33 (478.0)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	437 (36.42)	119.54 (478.0)
F_MAIN++APD_TL_L60	T-V-MNSP1 Import	Out = Nil, Lower 60 sec Service Requirement for a Mainland Network Event- loss of APD potlines due to undervoltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS	375 (31.25)	42.14 (-452.18)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	363 (30.25)	915.2 (1205.29)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	362 (30.17)	-87.04 (12.51)

2.5 Constraint Automation Usage

The constraint automation is an application in AEMO's energy management system (EMS) which generates thermal overload constraint equations based on the current or planned state of the power system. It is currently used by on-line staff to create thermal overload constraint equations for power system conditions where there were no existing constraint equations or the existing constraint equations did not operate correctly.

The following section details the reason for each invocation of the non-real-time constraint automation constraint sets and the results of AEMO's investigation into each case.

2.5.1 Further Investigation

Table 6 Non-Real-Time Constraint Automation usage

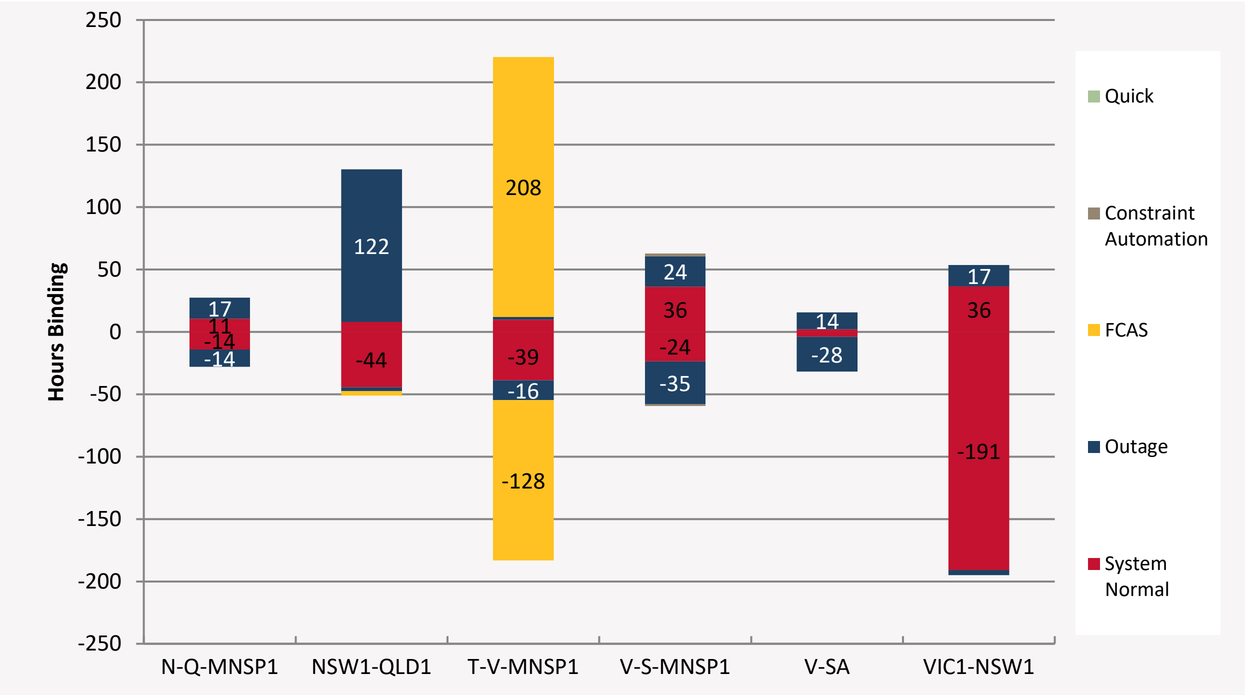
Constraint Set ID	Date Time	Description
CA_MQS_4C1211CB	11/06/2019 20:50 to 11/06/2019 23:35	Automated constraint equations were created to manage thermal overload on Waterloo to Templers 132kV line or Robertstown 275/132kV No.1 transformer for loss of the Robertstown to Para 275kV line during prior outages of Robertstown to Tungkillo 275kV line and Robertstown 275kV CB6571 and CB6572. Constraint equation S>>V_RBTU+CB_7 was created at a later stage to manage the thermal overload above.

2.6 Binding Dispatch Hours

This section examines the number of hours of binding constraint equations on each interconnector and by region. The results are further categorized into five types: system normal, outage, FCAS (both outage and system normal), constraint automation and quick constraints.

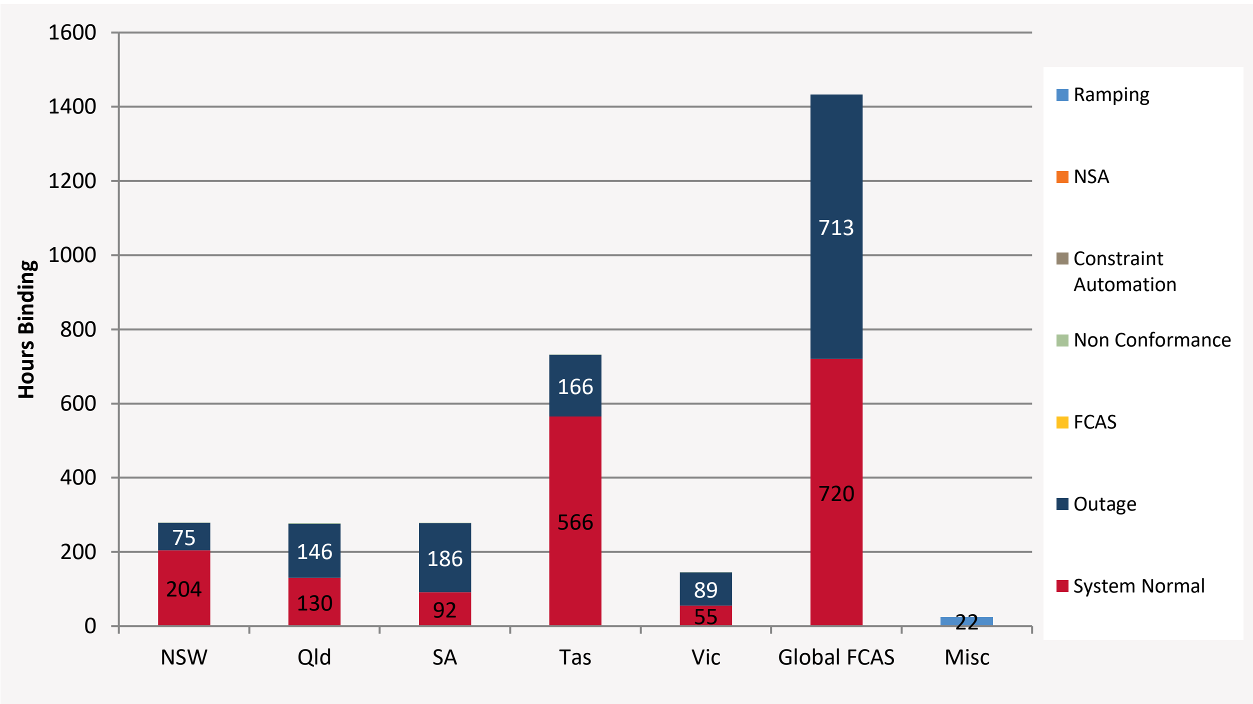
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

Figure 1 Interconnector binding dispatch hours



The regional comparison graph below uses the same categories as in Figure 1 as well as non-conformance, network support agreement and ramping. Constraint equations that cross a region boundary are allocated to the sending end region. Global FCAS covers both global and mainland requirements.

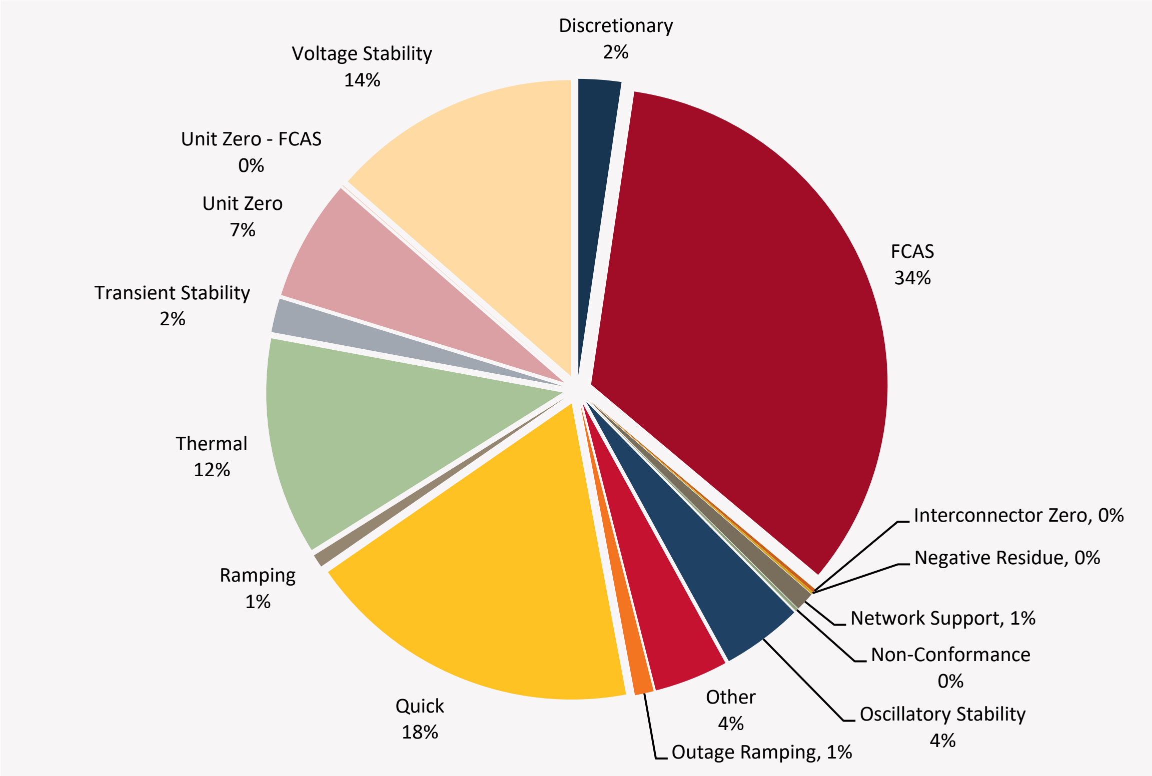
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for June 2019 that the different types of constraint equations bound.

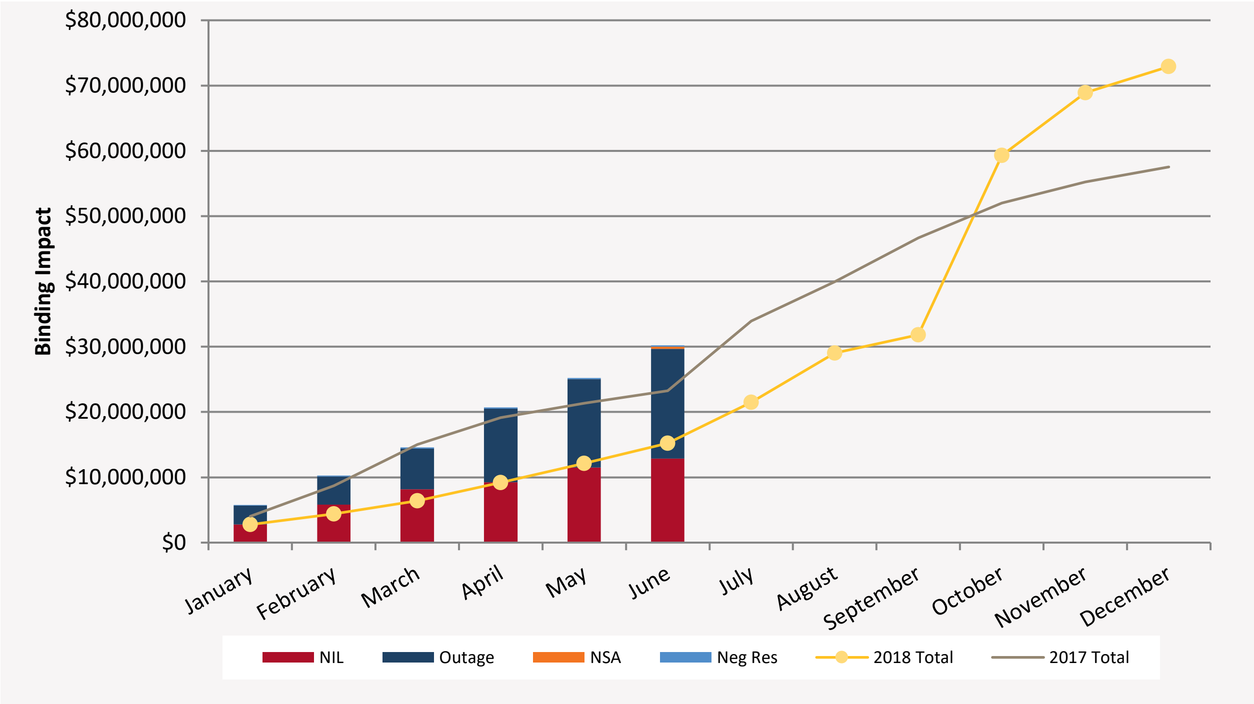
Figure 3 Binding by limit type



2.8 Binding Impact Comparison

The following graph compares the cumulative binding impact (calculated by summating the marginal values from the MCC re-run – the same as in section 2.2) for each month for the current year (indicated by type as a stacked bar chart) against the cumulative values from the previous two years (the line graphs). The current year is further categorised into system normal (NIL), outage, network support agreement (NSA) and negative residue constraint equation types.

Figure 4 Binding Impact comparison



2.9 Pre-dispatch RHS Accuracy

Pre-dispatch RHS accuracy is measured by the comparing the dispatch RHS value and the pre-dispatch RHS value forecast four hours in the future. The following table shows the pre-dispatch accuracy of the top ten largest differences for binding (in dispatch or pre-dispatch) constraint equations. This excludes FCAS constraint equations, constraint equations that violated in Dispatch, differences larger than ±9500 (this is to exclude constraint equations with swamping logic) and constraint equations that only bound for one or two Dispatch intervals. AEMO investigates constraint equations that have a Dispatch/Pre-dispatch RHS difference greater than 5% and ten absolute difference which have either bound for greater than 25 dispatch intervals or have a greater than $1,000 binding impact. The investigations are detailed in 2.9.1.

Table 7 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
Q_CLST_STRGTH_MEWF	Out = 855 or 8873 or 8874 or 856 or 8831, limit Mt Emerald WF to 50% capacity (26 turbines) if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=3 + Gladstone >=3 + (Stan+Cal+Glad >=10) + Haughton >0 + Sun Metals >0. Zero otherwise.	4	90,000,000 % (90.)	45,000,0 50% (90.)
Q_CLST_STRGTH_SMSF	Out = 855 or 8873 or 8874 or 856 or 8831, limit Sun Metals SF to 50% capacity (40 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=3 + Gladstone >=3 + (Stan+Cal+Glad >=10). Zero otherwise.	4	61,000,000 % (61.)	30,500,0 50% (61.)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	490	17,565% (504)	189% (150.34)
V^SML_KGRC_4	Out = Kerang to Wemen or Red Cliffs to Wemen 220kV line sections, or full Kerang to Wemen to Red Cliffs 220kV line, avoid voltage collapse for loss of Horsham to Ararat 220kV line	29	14,198% (101.97)	1,685% (46.89)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
T^^V_GTSH_1	Out = Sheffield to Georgetown 220 kV line, prevent voltage collapse at Georgetown 220 kV bus for loss of the remaining Sheffield to Georgetown 220kV line.	12	6,401% (91.31)	567% (36.48)
N^^V_DDWG	Out = 330 kV line between Dederang to Wodonga to Jindera to Wagga, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	10	1,726% (179.17)	568% (129.26)
N^^V_BUDP_1	Out = Buronga to Balranald to Darlington Pt (X5) 220 kV line, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	6	1,175% (166.97)	305% (130.85)
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	132	918% (9,479)	10.75% (176.37)
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	20	906% (131.27)	382% (65.12)
NSA_Q_BARCALDN	Network Support Agreement for Barcaldine GT to meet local islanded demand for the planned outage of 7153 T71 Clermont to H15 Lilyvale or 7154 T72 Barcaldine to T71 Clermont 132kV line	30	183% (12.96)	49.28% (6.36)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

NSA_Q_BARCALDN, N^^V_BUDP_1, N^^V_DDWG, Q_CLST_STRGTH_MEWF, Q_CLST_STRGTH_SMSF, S_NIL_STRENGTH_1, T^^V_GTSH_1, V^SML_KGRC_4: Investigated and no improvement can be made to the constraint equations at this stage.

N^^V_NIL_1: The Pre-dispatch formulation for this constraint equation was recalculated in early November 2017 (with an update to the limit advice). No further improvements can be made at this stage.

3. Generator / Transmission Changes

One of the main drivers for changes to constraint equations is from power system change, whether this is the addition or removal of plant (either generation or transmission). The following table details changes that occurred in for June 2019.

Table 8 Generator and transmission changes

Project	Date	Region	Notes
Coopers Gap Wind Farm	4 June 2019	QLD	New Generator
Clermont Solar Farm	18 June 2019	QLD	New Generator
Yendon Wind Farm	18 June 2019	VIC	New Generator

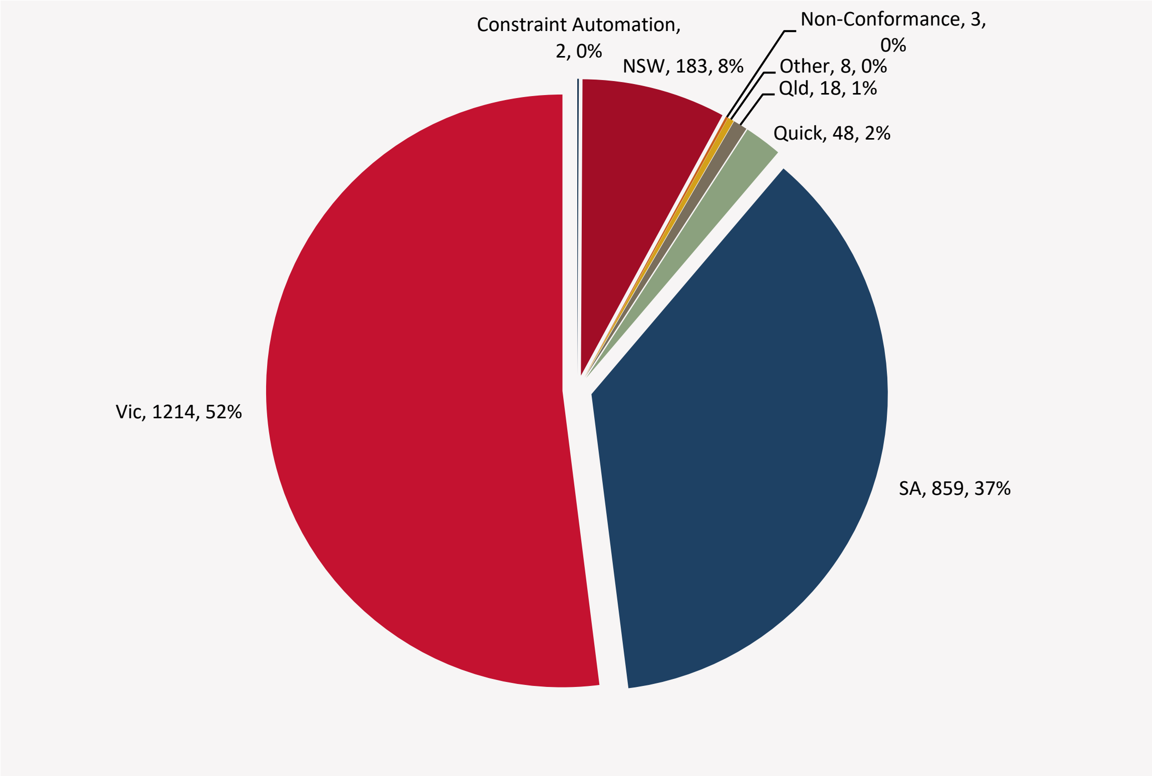
3.1 Constraint Equation Changes

The following pie chart indicates the regional location of constraint equation changes. For details on individual constraint equation changes refer to the Weekly Constraint Library Changes Report[2] or the constraint equations in the MMS Data Model.[3]

[2] AEMO. *NEM Weekly Constraint Library Changes Report*. Available at: http://www.nemweb.com.au/REPORTS/CURRENT/Weekly_Constraint_Reports/

[3] AEMO. *MMS Data Model*. Available at: http://www.aemo.com.au/Electricity/IT-Systems/NEM

Figure 5 Constraint equation changes



The following graph compares the constraint equation changes for the current year versus the previous two years. The current year is categorised by region.

Figure 6 Constraint equation changes per month compared to previous two years