AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

January 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 January 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	2176 (181.33)	19/12/2018
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	1819 (151.58)	20/12/2016
T_LIPM_PMWA_1_N-3	Out=Nil, loss of both Liapootah to Waddamana (tee) to Palmerston 220 kV lines and Palmerston to Waddamana 110 kV line classified credible, limit southern generators to <= southern load + 15 MW	1391 (115.91)	16/06/2016
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to be not exceed 45 MW with Broken Hill solar generating or 76 MW otherwise	1382 (115.16)	13/11/2018
VT_000	Vic to Tas on Basslink upper limit of 0 MW	532 (44.33)	05/08/2008
Q::N_NIL_AR_2L-G	Out=Nil, limit Qld to NSW on QNI to avoid transient instability for a 2L-G fault at Armidale	396 (33.0)	15/01/2018
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	386 (32.16)	11/01/2019
N>N-NIL_DC	Out= Nil, avoid O/L Armidale to Tamworth (85 or 86) on trip of the other Armidale to Tamworth line (85 or 86), Feedback	333 (27.75)	21/01/2019
V_T_NIL_BL1	Out=Nil, Basslink no go zone limits Vic to Tas	330	11/11/2014

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
		(27.5)	
T>T_NIL_BL_110_18_1	Out = Nil, avoid O/L the Lake Echo Tee to Waddamana No.1 line (flow to North) for loss of Tungatinah to Waddamana No.2 110 kV line, feedback	280 (23.33)	11/01/2019

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
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to be not exceed 45 MW with Broken Hill solar generating or 76 MW otherwise	1,678,286	13/11/2018
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	972,575	19/12/2018
V>>V_NIL_3	Out = Nil, avoid O/L either Dederang to South Morang 330 kV line (flow South) for trip of the parallel line, feedback	631,780	11/01/2019
V_GANWR_SF_BAT_50	Out = Nil, limit total output of Gannawarra Solar Farm and Battery (Gen component) to 50 MW to prevent overload on Gannawarra txfmr	558,544	24/01/2019
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	428,323	11/01/2019
S>NIL_NIL_NWMH2	Out= Nil, avoid O/L North West Bend-Monash #2 132kV on Nil trip, Feedback	336,327	11/01/2019
V::V_1900	Out=Nil, upper limit into Vic of 1900 MW	333,500	24/08/2018
S:V_500_HY_TEST	SA to VIC on Heywood upper transfer limit of 500 MW, limit for testing of Heywood interconnection upgrade.	264,769	07/08/2018
F_MAIN+NIL_DYN_RREG	Mainland Raise Regulation Requirement, Feedback in Dispatch, increase by 60 MW for each 1s of time error below -2.5s	260,991	12/12/2018
T_LIPM_PMWA_1_N-3	Out=Nil, loss of both Liapootah to Waddamana (tee) to Palmerston 220 kV lines and Palmerston to Waddamana 110 kV line classified credible, limit southern generators to <= southern load + 15 MW	239,026	16/06/2016

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.

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

Table 1 – Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V>>V_NIL_3	Out = Nil, avoid O/L either Dederang to South Morang 330 kV line (flow South) for trip of the parallel line, feedback	43 (3.58)	11/01/2019
F_T+NIL_WF_TG_R6	Out= Nil, Tasmania Raise 6 sec requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS	21 (1.75)	12/04/2016
T_WIND_100	Limit output of TAS wind generation to less than 100 MW. Note, due to 144 MW rating of Non-Scheduled Woolnorth Wind Farm, directions may be required to reduce Woolnorth MW output if this constraint violates	20 (1.66)	30/01/2019
V>>V_NIL_8	Out = Nil, avoid O/L DDTS to WOTS 330kV line for trip of LowerTumut-Wagga (051) + (991,990,99P) or (990,99M,970) ex_Yass lines - status switched ; Feedback	20 (1.66)	11/01/2019
V>>V_NIL_1A	Out = Nil, avoid O/L Murray to Dederang No.1 330kV line (flow MSS to DDTS) for loss of the parallel No.2 line, DBUSS-Line control scheme enabled, 15 min line ratings, feedback	11 (0.91)	11/01/2019
NSA_V_BDL02_20	Bairnsdale Unit 2 >= 20 MW for Network Support Agreement	8 (0.66)	21/08/2013
V>>V_NIL_1B	Out = Nil, avoid O/L Murray to Dederang No.2 330kV line (flow MSS to DDTS) for loss of the parallel No.1 line, DBUSS-Line control scheme enabled, 15 min line ratings, feedback	5 (0.41)	11/01/2019
T_LIPM_PMWA_1_N-3	Out=Nil, loss of both Liapootah to Waddamana (tee) to Palmerston 220 kV lines and Palmerston to Waddamana 110 kV line classified credible, limit southern generators to <= southern load + 15 MW	5 (0.41)	16/06/2016
N>N-ARKS_TE_A1	Out= Armidale to Kempsey (965), avoid O/L Armidale to Coffs Harbour (96C) on trip of Armidale to Coffs Harbour (87), Swamp out when all 3 directlink cable O/S, Feedback, TG formulation in PD/ST	5 (0.41)	25/02/2016
NSA_V_BDL02_30	Bairnsdale Unit 2 >= 30 MW for Network Support Agreement	5 (0.41)	21/08/2013

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Table 2 – Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
V>>V_NIL_3	Constraint equation violated for 43 DIs, consecutive for the following intervals:

Constraint Equation ID (System Normal Bold)	Description
	• 6 DIs on 24/01/2019, between 1640hrs and 1705hrs • 7 DIs on 24/01/2019, between 1745hrs and 1815hrs • 27 DIs on 25/01/2019, between 1055hrs and 1305hrs Max violation of 344.37 MW occurred on 25/01/2019 at 1135hrs. Constraint equation violated due to a combination of supply deficit and high demand associated with high temperature in Victoria on 24 and 25 January 2019. All supply and demand response options had been exhausted. Contingency analysis reported violations during this time, but these did not exceed 30 minutes of violations.
F_T+NIL_WF_TG_R6	Constraint equation violated for 21 DIs, 7 of which were consecutive. Max violation of 14.18 MW occurred on 23/01/2019 at 0720hrs. Constraint equation violated due to Tasmania raise 6 second service availability from generators being less than requirement.
T_WIND_100	Constraint equation violated for 20 non-consecutive DIs. Max violation of 171.98 MW occurred on 31/01/2019 at 0520hrs. Constraint equation violated due to non-scheduled wind farms Bluff Point and Studland Bay output exceeding 100 MW.
V>>V_NIL_8	Constraint equation violated for 20 DIs, 17 of which were consecutive. Max violation of 47.06 MW occurred on 14/01/2019 at 1945hrs. Constraint equation violated due to competing requirement with the import limit on the Murraylink interconnector. The system was secure in which the constraint violated. This constraint equation is currently being investigated by the Constraint Builders.
V>>V_NIL_1A	Constraint equation violated for 11 DIs, 6 of which were consecutive. Max violation of 168.4 MW occurred on 25/01/2019 at 1135hrs. Constraint equation violated due to the same reason as V>>V_NIL_3.
NSA_V_BDL02_20	Constraint equation violated for 8 non-consecutive DIs. Constraint equation violated for 4 DIs on 03/01/2019 from 1605hrs to 1620hrs with a violation degree of 20 MW for each DI. Constraint equation violated due to Bairnsdale unit 1 being placed in service instead of unit 2. Bairnsdale operators were advised, and unit 2 came online shortly after. The other 4 DIs on 31/01/2019 from 1605hrs to 1620hrs with a violation degree of 20 MW for each DI. Constraint equation violated due to Bairnsdale unit 2 being limited by its start-up profile.
V>>V_NIL_1B	Constraint equation violated for 5 DIs. Max violation of 149.11 MW occurred on 25/01/2019 at 1135hrs. Constraint equation violated due to the same reason as V>>V_NIL_3.
T_LIPM_PMWA_1_N-3	Constraint equation violated for 5 DIs. Max violation of 74.97 MW occurred on 31/01/2019 at 0520hrs. Constraint equation violated because it was invoked without ramping (which is standard practice for reclassifications) following the reclassification of both Liapootah to Waddamana to Palmerston 220 kV lines and Palmerston to Waddamana 110 kV line as credible due to bushfires in Tasmania.
N>N-ARKS_TE_A1	Constraint equation violated for 5 DIs. Max violation of 30.5 MW occurred on 10/01/2019 at 1850hrs. Constraint equation violated due to competing requirement with the Terranora interconnector import limit set by QNTE_ROC.
NSA_V_BDL02_30	Constraint equation violated for 5 DIs. Max violation of 30 MW occurred on 31/01/2019 at 0705hrs. Constraint equation violated due to Bairnsdale unit 2 being limited by its start-up profile.

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	2142 (178.5)	-229.69 (-659.62)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	1558 (129.83)	-405.43 (-477.99)
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	1514 (126.17)	-72.27 (-477.99)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	547 (45.58)	7.23 (478.0)
VT_000	T-V-MNSP1 Import	Vic to Tas on Basslink upper limit of 0 MW	532 (44.33)	0.0 (0.0)
Q::N_NIL_AR_2L-G	NSW1-QLD1 Import	Out=Nil, limit Qld to NSW on QNI to avoid transient instability for a 2L-G fault at Armidale	378 (31.5)	-1115.52 (-1145.21)
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	369 (30.75)	-100.63 (-476.64)
N>N-NIL_DC	N-Q-MNSP1 Import	Out= Nil, avoid O/L Armidale to Tamworth (85 or 86) on trip of the other Armidale to Tamworth line (85 or 86), Feedback	307 (25.58)	-128.09 (-198.69)
N>N-NIL_DC	NSW1-QLD1 Import	Out= Nil, avoid O/L Armidale to Tamworth (85 or 86) on trip of the other Armidale to Tamworth line (85 or 86), Feedback	305 (25.42)	-1016.7 (-1131.45)
F_T++NIL_BLSPS_L6_1	T-V-MNSP1 Export	Tasmania Lower 6 sec Requirement for loss of Basslink, Segment 1, FCSPS unavailable	285 (23.75)	103.41 (192.27)

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

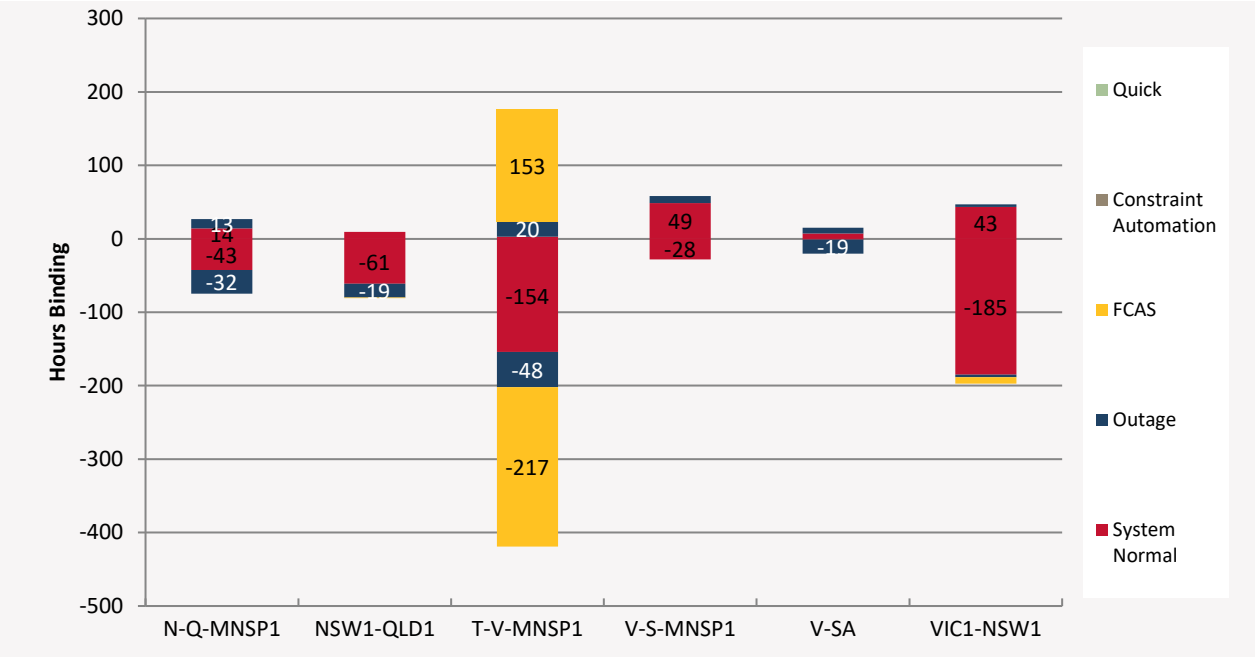
Non-real time constraint automation was not used.

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.

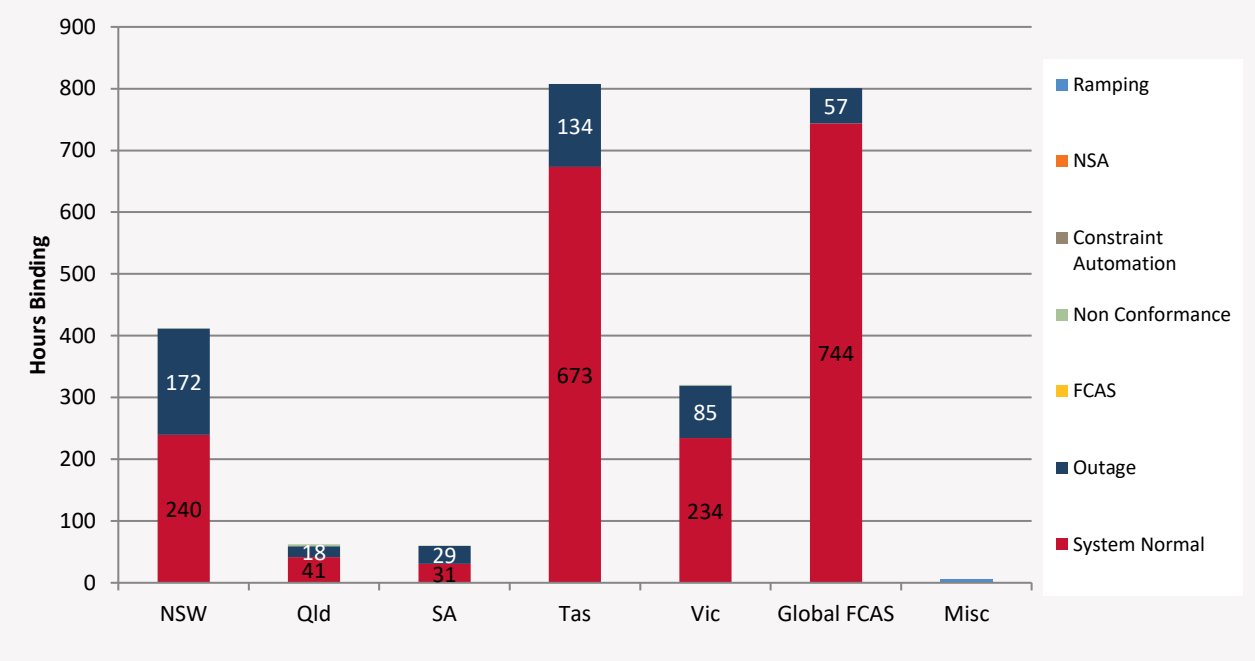
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

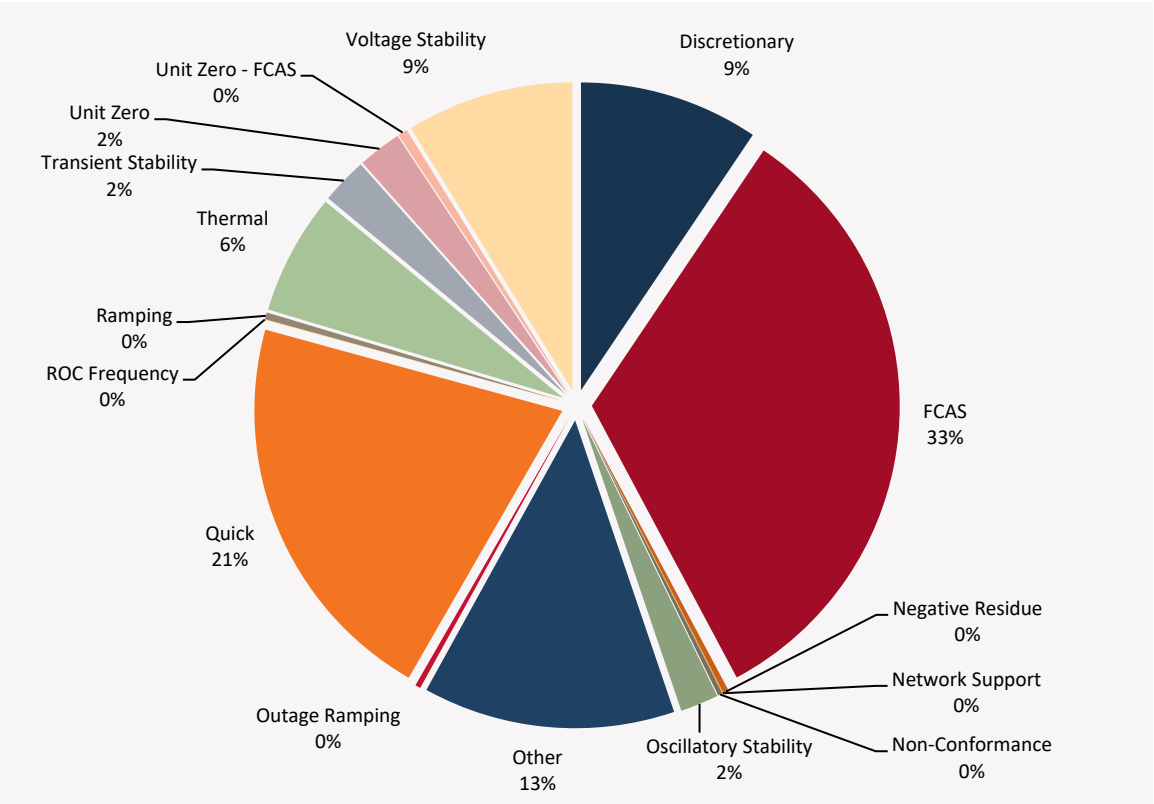
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

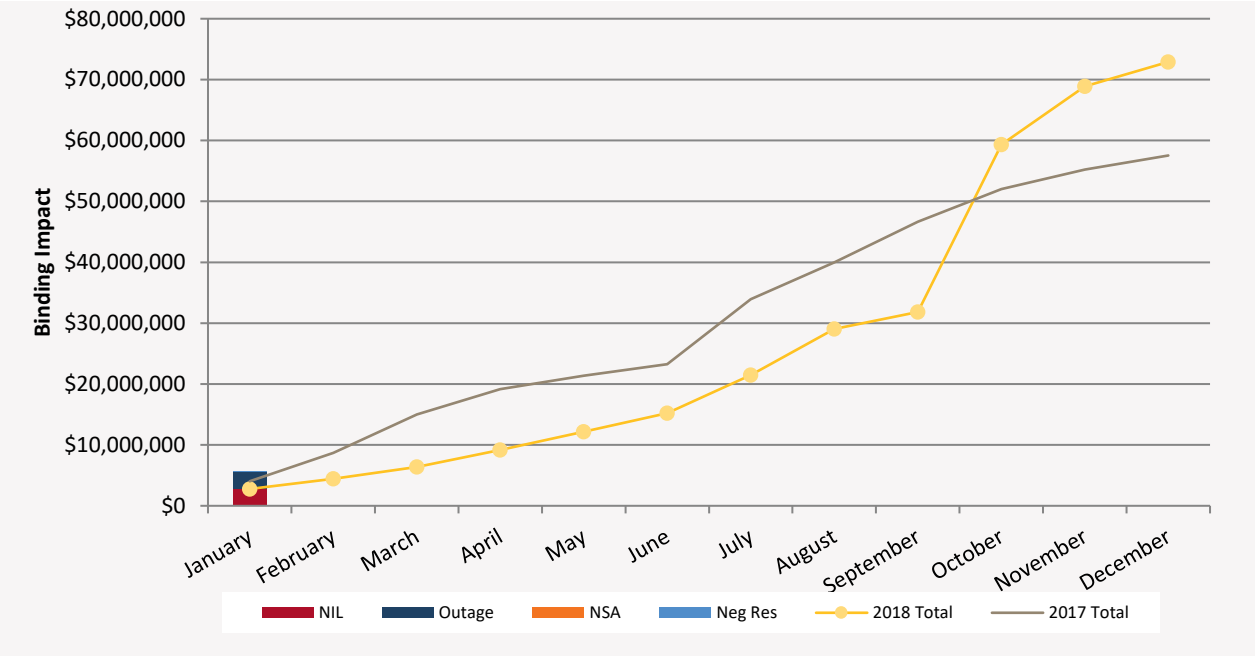
Figure 3 Binding by limit type



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 6 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V>SML_NSWRB_10	Out = NSW Murraylink runback scheme, avoid O/L of Kerang to Wemen 220 kV line section for loss of Balranald to Darlington Point (X5/1) 220 kV line, feedback	12	1,955% (390.52)	868% (262.17)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	439	756% (358.53)	32.44% (58.15)
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	11	722% (88.68)	170% (37.49)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
T_WIND_100	Limit output of TAS wind generation to less than 100 MW. Note, due to 144 MW rating of Non-Scheduled Woolnorth Wind Farm, directions may be required to reduce Woolnorth MW output if this constraint violates	9	631% (88.39)	237% (33.91)
V::N_NIL_V2	Out = NIL, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	34	473% (324.28)	44.06% (80.61)
V^SML_BUDP_3	Out = Buronga to Balranald to Darlington Pt (X5) 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	3	400% (72.53)	231% (67.73)
V>>V_NIL_8	Out = Nil, avoid O/L DDTS to WOTS 330kV line for trip of LowerTumut-Wagga (051) + (991,990,99P) or (990,99M,970) ex_Yass lines - status switched ; Feedback	14	210% (221.61)	149.36% (176.94)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	481	109.27% (619)	40.94% (193.93)
Q>NIL_MUTE_757	Out= Nil, ECS for managing 757 H4 Mudgeeraba to T174 Terranora 110kV line, Summer and Winter ECS ratings selected by SCADA status.	4	98.33% (99.95)	86.14% (99.95)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	8	96.67% (29.)	35.81% (11.66)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V>SML_NSWRB_10, V^SML_HORC_3, T_WIND_100, V::N_NIL_V2, V>>V_NIL_8:
Investigated and no improvement can be made to the constraint equation at this stage.

V_T_NIL_FCSPS: This constraint equation uses analogue values for the load enabled for the FCSPS in Pre-dispatch. This value can change quickly in dispatch and this is not possible to predict in Pre-dispatch. No changes proposed.

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.

Q>NIL_MUTE_757: Investigated. Mismatch was due to difference between modelling of Terranora control scheme and line status between DS and PD. No improvement can be made to the constraint equation 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 January 2019.

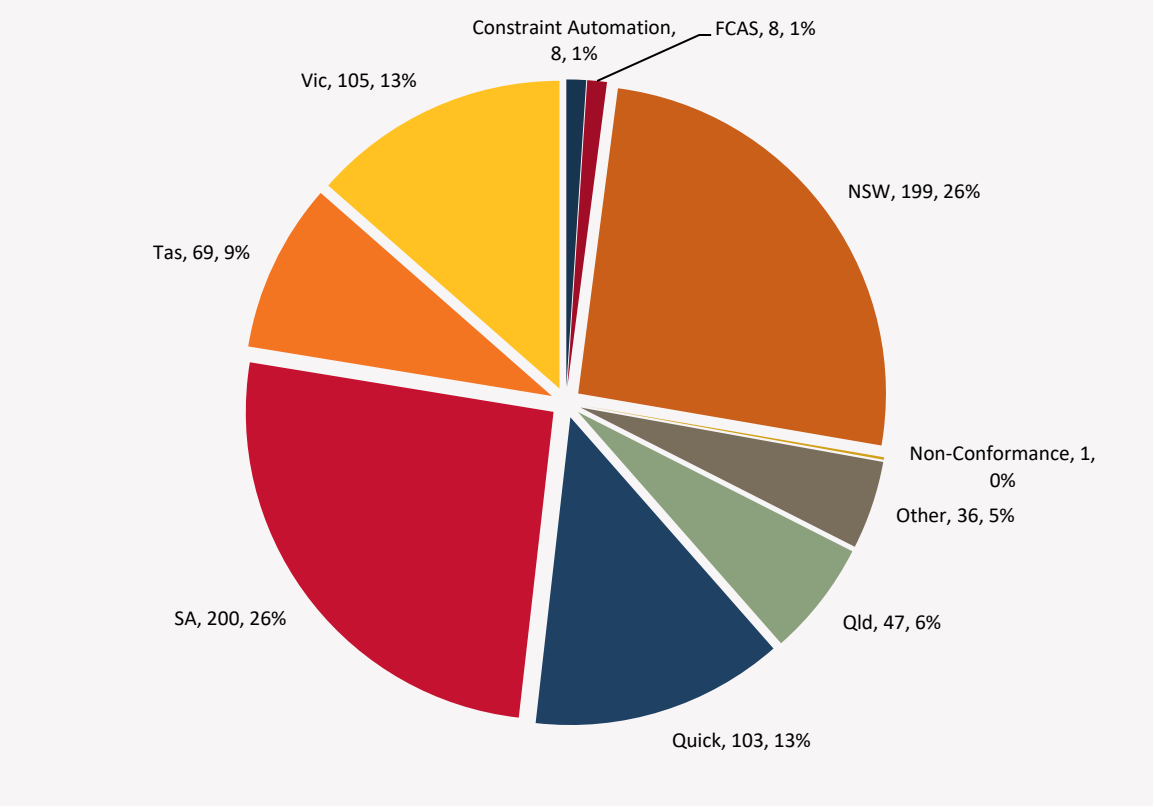
Table 7 Generator and transmission changes

Project	Date	Region	Notes
Childers Solar Farm	25 January 2019	QLD	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]

Figure 5 Constraint equation changes



[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

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