AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

DECEMBER 2018

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 December 2018. 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^N-LS_SVC	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; TG formulation only	2783 (231.91)	27/08/2018
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	1103 (91.91)	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	1093 (91.08)	19/12/2018
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	791 (65.91)	25/11/2013
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.	668 (55.66)	05/12/2018
N>N-NIL_DC	Out= Nil, avoid O/L Armidale to Tamworth (86) on trip of Armidale to Tamworth (85) line, Feedback	460 (38.33)	22/08/2018
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	458 (38.16)	25/11/2013
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	454 (37.83)	05/03/2014
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	363	20/12/2016

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
		(30.25)	
S>>PARB_RBTU_WEWT	Out=Para-Robertstown 275kV line, avoid O/L Waterloo East-Waterloo 132kV on trip of Robertstown-Tungkillo 275kV line, Feedback	315 (26.25)	11/09/2018

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	1,200,415	13/11/2018
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.	694,799	05/12/2018
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	260,515	05/03/2014
S>X_RBPA+CB_01	Out= Robertstown-Para 275kV line and Robertstown CB6574 and CB6575, avoid O/L Robertstown 275/132kV TX1 on trip of Robertstown-Tungkillo 275kV line (this offloads Robertstown 275/132kV TX2), Feedback	217,845	19/12/2018
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	156,003	12/12/2018
N_STWF1_ZERO	Silverton wind farm upper limit of 0 MW	149,651	06/02/2018
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	138,615	19/12/2018
S_WATERLWF_RB	Out= Nil, Limit Waterloo WF output to its runback MW capability, DS only	108,360	22/06/2017
F_I+NIL_MG_R5	Out = Nil, Raise 5 min requirement for a NEM Generation Event	97,214	21/08/2013
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	90,634	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

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
N^N-LS_SVC	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; TG formulation only	10 (0.83)	27/08/2018
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	7 (0.58)	30/04/2018
F_T+LREG_0050	Tasmania Lower Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	3 (0.25)	29/01/2015
S>NIL_SGBN_SGSE-T2	Out= NIL, avoid O/L Snuggery Mayura -South East T 132kV line on trip of Snuggery-Blanche 132kV line (for Line component SECS assumed O/S), Feedback	3 (0.25)	13/09/2016
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	2 (0.16)	12/04/2016
N_SILVERWF_WT	Limit number of turbine online for Silverton wind farm to be not exceed 13 with Broken Hill solar generating or 22 otherwise	1 (0.08)	13/11/2018
NC_N_URANQ14	Non Conformance Constraint for Uranquinty 4 Power Station	1 (0.08)	21/08/2013
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	1 (0.08)	29/01/2015
N^^Q_LS_VC_B1	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	1 (0.08)	19/01/2018

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
N^N-LS_SVC	Constraint equation violated for 10 non-consecutive DIs during the month. Max violation of 28 MW occurred on 05/12/2018 from 0605hrs to 0615hrs. Constraint equation violated due to competing requirement with the various constraints that set the Terranora interconnector import limit.
F_T_NIL_MINP_R6	Constraint equation violated for 7 non-consecutive DIs during the month. Max violation of 25.97 MW occurred on 01/12/2018 at 0925hrs. Constraint equation violated due to Tasmania raise 6 second service availability from generators being less than requirement.
F_T+LREG_0050	Constraint equation violated for 3 DIs during the month. Max violation of 17.88 MW occurred on 02/12/2018 at 0105hrs. Constraint equation violated due to Tasmania lower regulation service availability less than the requirement.

Constraint Equation ID (System Normal Bold)	Description
S>NIL_SGBN_SGSE-T2	Constraint equation violated for 3 DIs during the month. Max violation of 10.92 MW occurred on 13/12/2018 at 0930hrs. Constraint equation violated due to Lake Bonney 2 and Lake Bonney 3 being limited by its ramp down rate.
F_T+NIL_WF_TG_R6	Constraint equation violated for 2 DIs during the month. Max violation of 5.29 MW occurred on 24/12/2018 at 0205hrs. Constraint equation violated due to Tasmania raise 6 second service availability from generators being less than requirement.
N_SILVERWF_WT	Constraint equation violated for 1 DI on 07/12/2018 at 0555hrs with a violation degree of 16.17 MW. Constraint equation violated due to Silverton wind farm being limited by its ramp down rate.
NC_N_URANQ14	Constraint equation violated for 1 DI on 13/12/2018 at 1735hrs with a violation degree of 11.6 MW. Constraint equation violated due to interaction with the unit fast start inflexibility profile.
F_T+RREG_0050	Constraint equation violated for 1 DI on 02/12/2018 at 0105hrs with a violation degree of 7.32 MW. Constraint equation violated due to Tasmania raise regulation service availability less than the requirement.
N^^Q_LS_VC_B1	Constraint equation violated for 1 DI on 14/12/2018 at 1540hrs with a violation degree of 2.42 MW. Constraint equation violated due to completing requirement with the Terranora interconnector import limit set by Q>NIL_MUTE_757.

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^N-LS_SVC	N-Q-MNSP1 Export	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; TG formulation only	2658 (221.5)	-65.21 (20.97)
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 under voltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS	1247 (103.92)	44.6 (-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	1208 (100.67)	227.85 (478.0)
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	1093 (91.08)	-383.24 (-751.8)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	791 (65.92)	-81.08 (-113.2)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able to transfer FCAS	541 (45.08)	272.32 (478.0)
N>N-NIL_DC	NSW1-QLD1 Import	Out= Nil, avoid O/L Armidale to Tamworth (86) on trip of Armidale to Tamworth (85) line, Feedback	460 (38.33)	-996.54 (-1093.91)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N_X_MBTE_3B	N-Q-MNSP1 Import	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	455 (37.92)	-19.81 (-53.2)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able to transfer FCAS	405 (33.75)	156.85 (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 under voltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS	319 (26.58)	-153.69 (-473.0)

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.

Non-real time constraint automation was not used.

2.5.1 Further Investigation

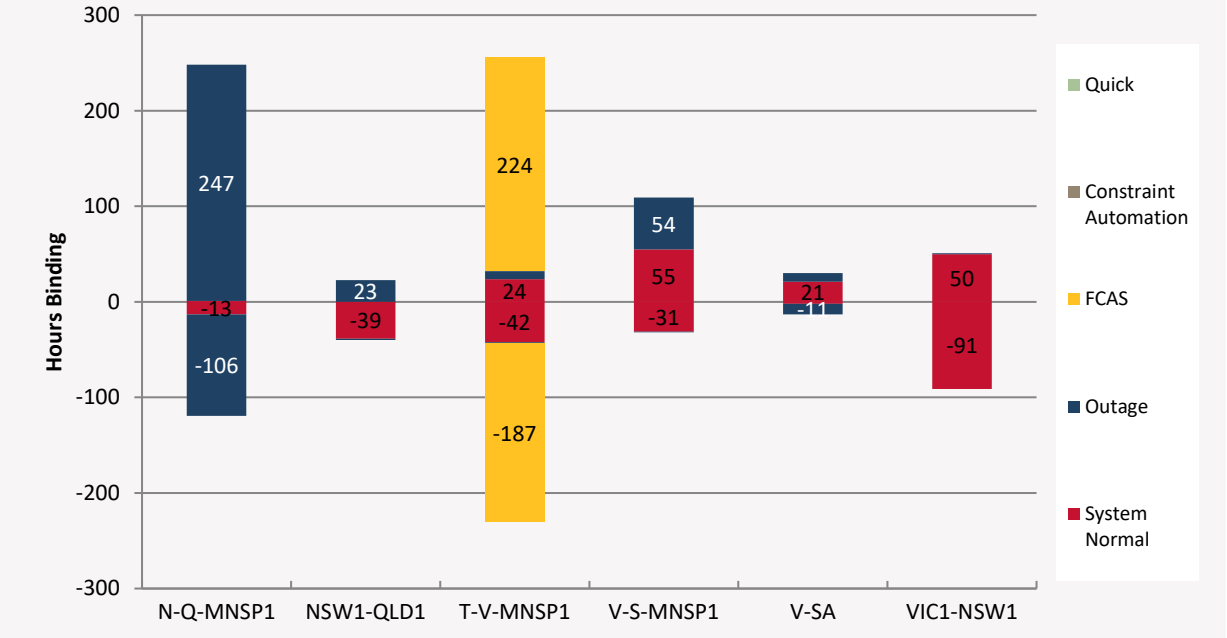
Non-real time constraint automation was not used.

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.

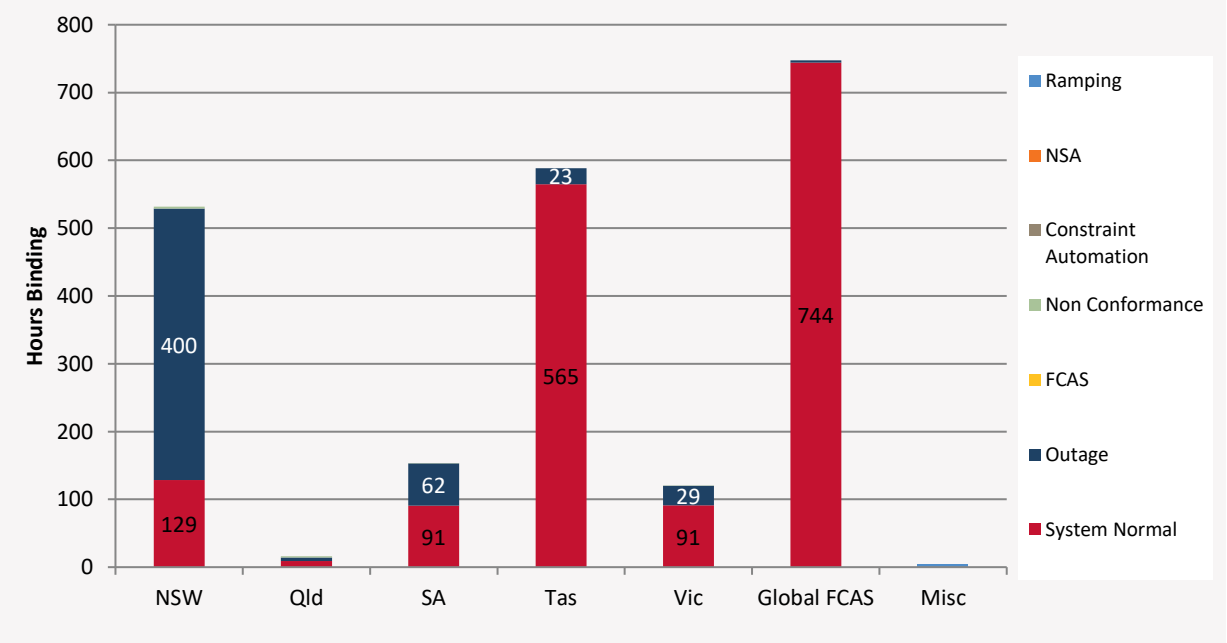
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

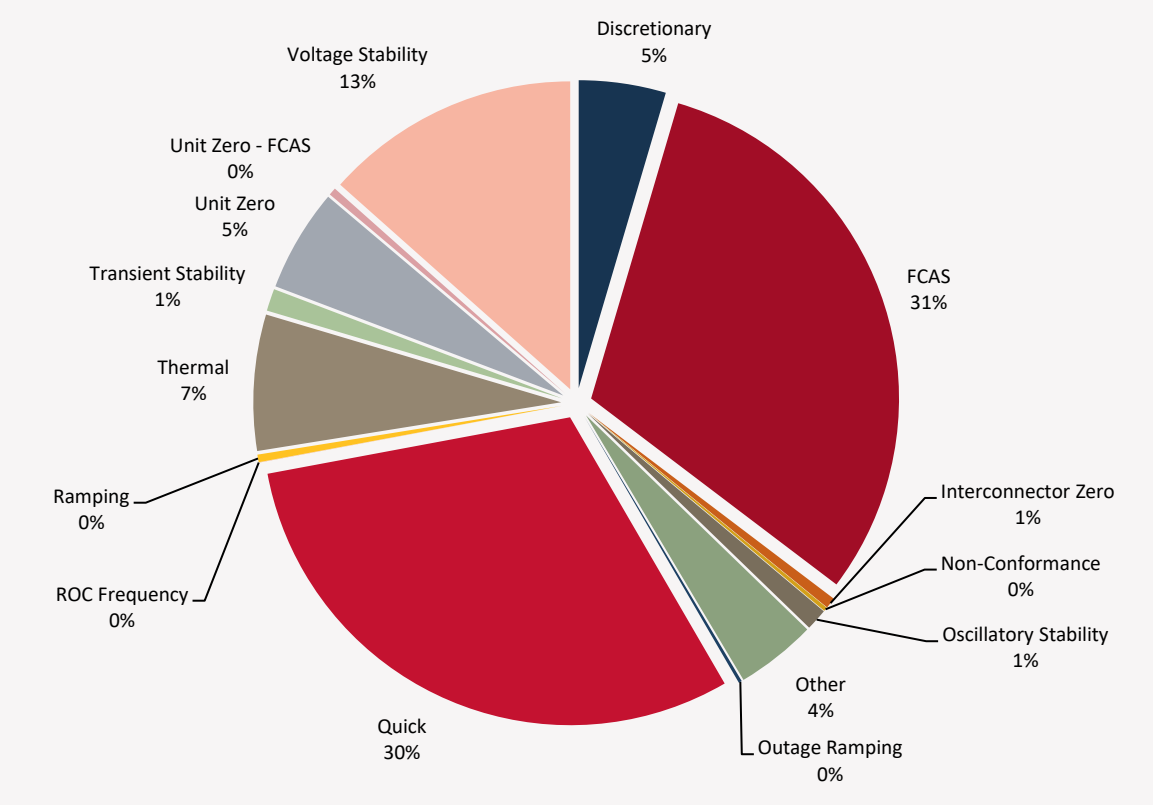
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from December 2018 that the different types of constraint equations bound.

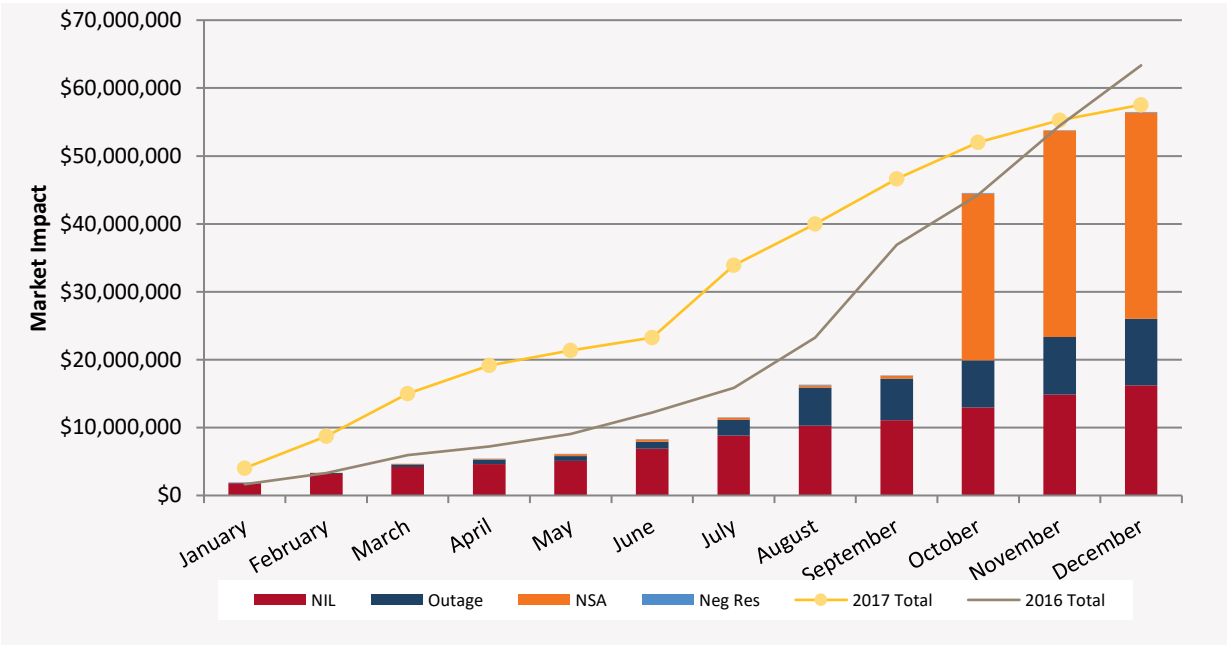
Figure 3 Binding by limit type



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
N^N-LS_SVC	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; TG formulation only	535	209,029% (174.47)	657% (28.05)
V::N_NIL_S2	Out = NIL, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	21	42,500% (410.22)	2,157% (90.57)
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	4	29,245% (101.86)	9,045% (84.18)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	76	331% (386.14)	17.51% (44.43)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	68	75.56% (31.5)	33.8% (9.23)
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.	46	74.7% (149.23)	15.61% (51.94)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	31	70% (31.5)	23.81% (10.38)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	257	64.92% (419.71)	28.14% (99.64)
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.	21	63.17% (127.1)	17.46% (38.77)
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	55	57.32% (418.59)	17.93% (126.68)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^^N_NIL_1, V::N_NIL_S2, V::N_NIL_V2, T^^V_GTSH_1: Investigated and no improvement can be made to the constraint equations at this stage.

N_X_MBTE_3A, N_X_MBTE_3B: Investigated and the mismatch was due to issues with forecasting of the Terranora load. The forecasting of the Terranora load has been improved in November 2018.

N^N-LS_SVC: Investigated and constraint equation was updated on 27/08 to improve PD performance.

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.

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 December 2018.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Susan River Solar Farm	18 December 2018	QLD	New Generator

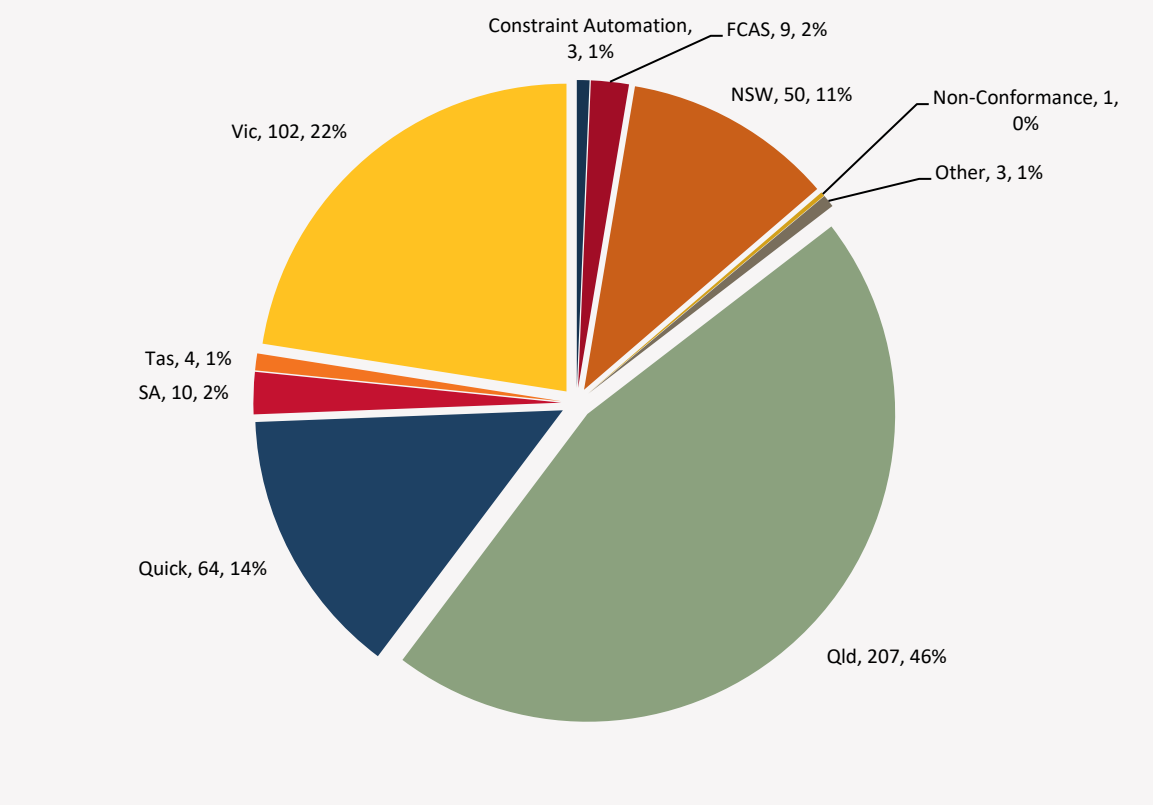
3.1 Constraint Equation Changes

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]

[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