Monthly Constraint Report

November 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 November 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^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	1788 (149.0)	04/09/2018
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	1371 (114.25)	27/08/2018
S>SE6161_SETX2_SGBL	Out= South East 132kV CB6161, avoid O/L Snuggery-Blanche 132kV line on trip of South East 132/275 TX2 (this offloads Mayura-South East T 132kV line), Feedback	803 (66.91)	09/09/2016
T>T_HAPM_2A	Out = Hadspen to Palmerston 220 kV line, avoid O/L Hadspen to Palmerston 220 kV line (flow North) for trip of Palmerston to Sheffield 220 kV line considering NCSPS action, ensure sufficient NCSPS generation dispatched.	473 (39.41)	09/10/2018
N^^Q_LS_VC_B1	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	464 (38.66)	19/01/2018
S_NIL_STRENGTH_1	Upper limit of 1295 MW for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required combination is online.	462 (38.5)	26/11/2018
N^^Q_NIL_B1	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	426 (35.5)	06/12/2017
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	333 (27.75)	13/11/2018

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	266 (22.16)	05/03/2014
VSML_ZERO	Vic to SA on ML upper transfer limit of 0 MW	233 (19.41)	21/08/2013

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>SE6161_SETX2_SGBL	Out= South East 132kV CB6161, avoid O/L Snuggery-Blanche 132kV line on trip of South East 132/275 TX2 (this offloads Mayura-South East T 132kV line), Feedback	601,072	09/09/2016
S_NIL_STRENGTH_1	Upper limit of 1295 MW for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required combination is online.	494,588	26/11/2018
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	362,227	13/11/2018
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	284,297	05/03/2014
V_BANNERTON_ZERO	Bannerton Solar Farm upper limit of 0 MW	216,496	23/05/2018
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	177,530	12/10/2018
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	177,084	04/09/2018
F_I+NIL_MG_R5	Out = Nil, Raise 5 min requirement for a NEM Generation Event	125,592	21/08/2013
N_BODWF1_ZERO	Bodangora wind farm upper limit of 0 MW	111,575	05/04/2018
N_COLEASF1_ZERO	Coleambally solar farm upper limit of 0 MW	94,022	19/06/2018

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
S>SE6161_SETX2_SGBL	Out= South East 132kV CB6161, avoid O/L Snuggery-Blanche 132kV line on trip of South East 132/275 TX2 (this offloads Mayura-South East T 132kV line), Feedback	24 (2.0)	09/09/2016
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	23 (1.91)	06/05/2015
N>N-ARKK_CH_CB892A	Out= Armidale to Koolkhan (966) and Coffs Harbour CB 892 opened, avoid O/L Armidale to Coffs Harbour (96C)132kV line, on trip of Armidale to Coffs Harbour (87) 330kV line, Swamp out when all 3 directlink cable O/S, Feedback. TG formulation in PD/ST	17 (1.41)	11/01/2016
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	6 (0.5)	30/04/2018
S_HPRG1_E	Out= Nil, Hornsdale Battery generation energy target <= 30 MW	3 (0.25)	13/12/2017
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	3 (0.25)	04/05/2018
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	2 (0.16)	29/01/2015
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
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	1 (0.08)	12/10/2018
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 able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	1 (0.08)	12/04/2016

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
S>SE6161_SETX2_SGBL	Constraint equation violated for 24 non-consecutive DIs with a max violation of 4.1 MW, which occurred on 22/11/2018 at 1150hrs. Constraint equation violated due to high non-scheduled generation from Lake Bonney 1 wind farm at the time of the outage of the nearby South East 132kV CB6161.

Constraint Equation ID (System Normal Bold)	Description
NSA_Q_BARCALDN	Constraint equation violated for 23 DIs, 7 of which occurred consecutively on 19/11/2018 and another 7 of which occurred consecutively on 22/11/2018. Max violation of 20.11 MW occurred on 19/11/2018 at 0855hrs. This constraint reflects the Network Support Agreement under which Barcaldine supplied the local islanded load following a planned transmission line outage. The violation of this constraint does not represent an insecure operating state. Constraint equation violated due to the value for max availability not matching local demand.
N>N-ARKK_CH_CB892A	Constraint equation violated for 17 non-consecutive DIs (most of which were alternate). Max violation of 83.34 MW occurred on 07/11/2018 at 1355hrs. Constraint equation violated due competing requirement with Terranora interconnector import limit which was set by QNTE_ROC.
F_T_NIL_MINP_R6	Constraint equation violated for 6 DIs. Max violation of 16.78 MW occurred on 10/11/2018 at 0550hrs. Constraint equation violated due to Tasmania raise 6 second service availability from generators being less than the requirement.
S_HPRG1_E	Constraint equation violated for 3 DIs, with a max violation of 40 MW occurring on 27/11/2018 at 0945hrs. Constraint equation violated due to testing activities associated with the System Integrity Protection Scheme (SIPS).
F_T_AUFLS2_R6	Constraint equation violated for 3 DIs. Max violation of 22.36 MW occurred on 7/11/2018 at 1405hrs. Constraint equation violated due to Tasmania raise 6 second service availability from generators less than the requirement.
F_T+RREG_0050	Constraint equation violated for 2 DIs. Max violation of 41.54 MW occurred on 10/11/2018 at 0555hrs. Constraint equation violated due to Tasmania raise regulation service availability less than the requirement, which increased ahead of a planned outage on the Basslink interconnector.
F_T+NIL_WF_TG_R6	Constraint equation violated for 2 DIs. Max violation of 2.02 MW occurred on 08/11/2018 at 1150hrs. Constraint equation violated due to a combination of Tasmania raise 6 second service availability from generators being less than requirement and a competing requirement from constraint F_T_AUFLS2_R6 which limits the service enablement from loads.
F_MAIN+NIL_DYN_RREG	Constraint equation violated for 1 DI on 07/11/2018 at 1400hrs with a violation degree of 59.76 MW. Constraint equation violated due to mainland raise regulation service availability being less than requirement, which was increased due to accumulated negative time error.
F_T++NIL_WF_TG_R6	Constraint equation violated for 1 DI on 07/11/2018 at 1405hrs with a violation degree of 23.09 MW. Constraint equation violated due to competing requirements from constraints F_T_AUFLS2_R6 and T_V_NIL_FCSPS, the latter of which set the Basslink export limit and thereby limited its FCAS transfer capability.

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)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	2642 (220.17)	32.02 (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	1788 (149.0)	-397.98 (-805.59)

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	1592 (132.67)	149.36 (-389.21)
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	1175 (97.92)	-38.5 (34.74)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	597 (49.75)	139.06 (477.99)
N^^Q_LS_VC_B1	NSW1-QLD1 Export	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	464 (38.67)	323.64 (426.88)
N^^Q_NIL_B1	NSW1-QLD1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	426 (35.5)	251.67 (371.87)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	397 (33.08)	27.62 (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	353 (29.42)	122.97 (54.3)
N^^Q_NIL_B1	N-Q-MNSP1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	316 (26.33)	49.04 (96.1)

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

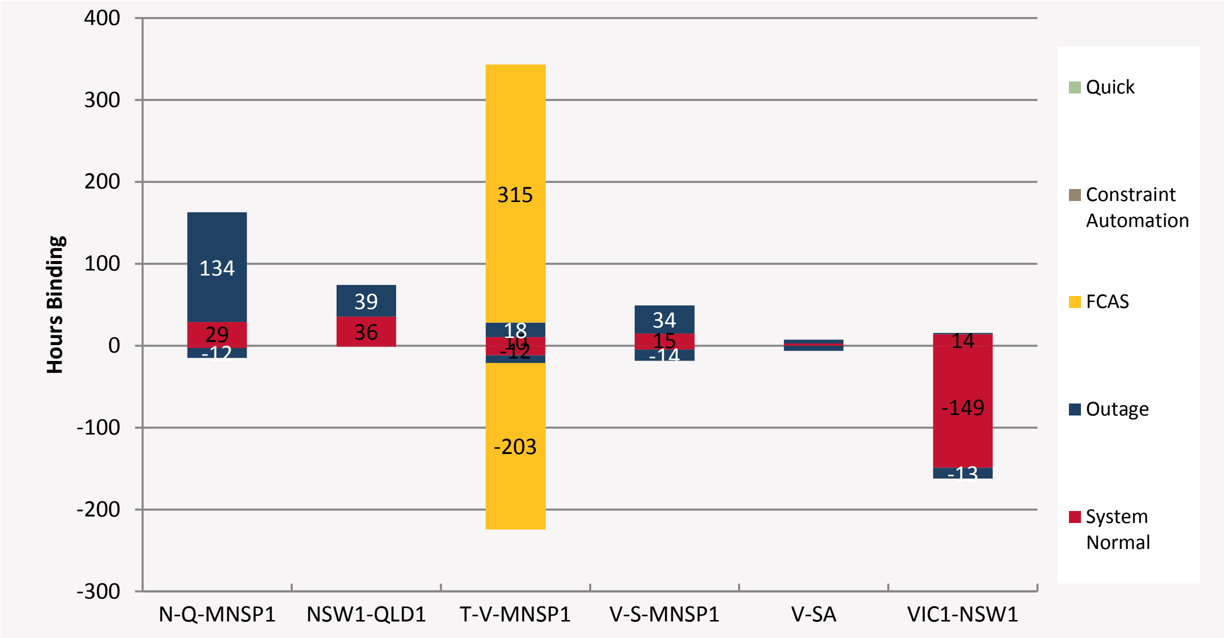
Non-real time constraint automation was not used.

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.

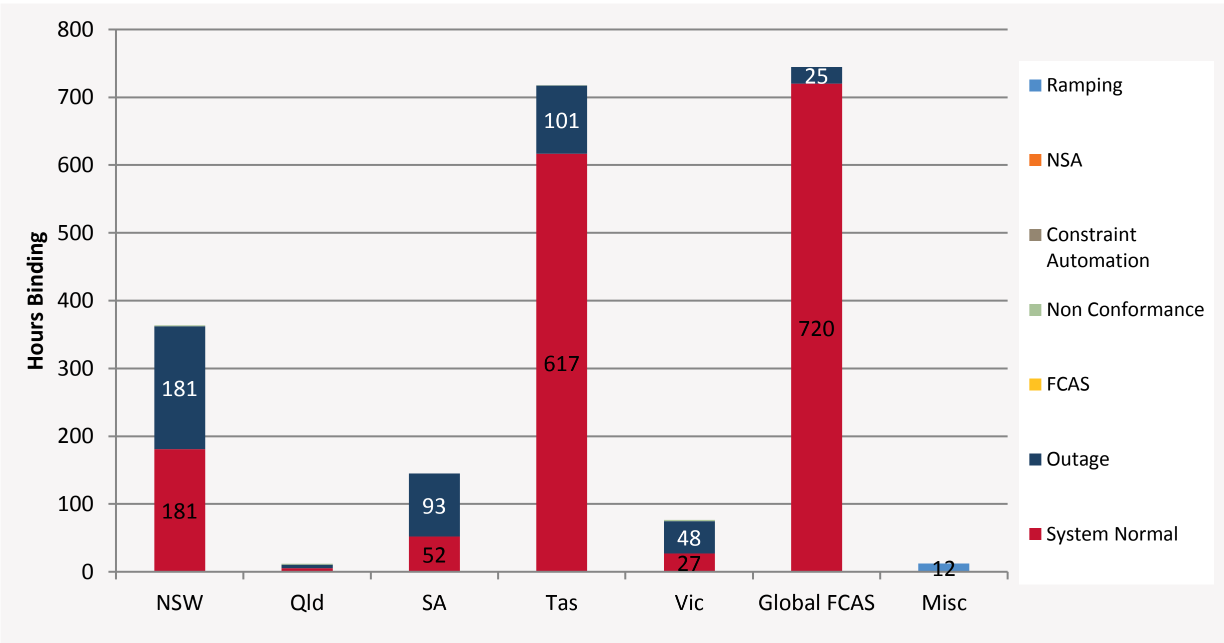
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

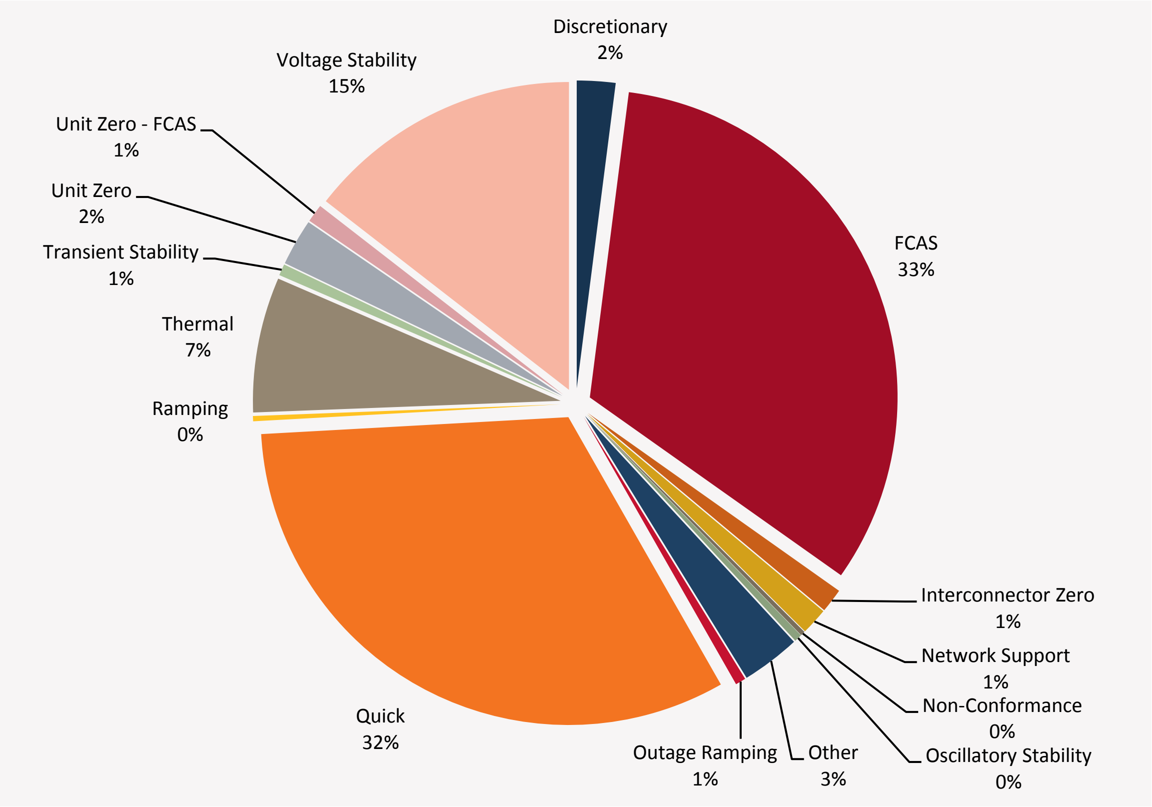
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

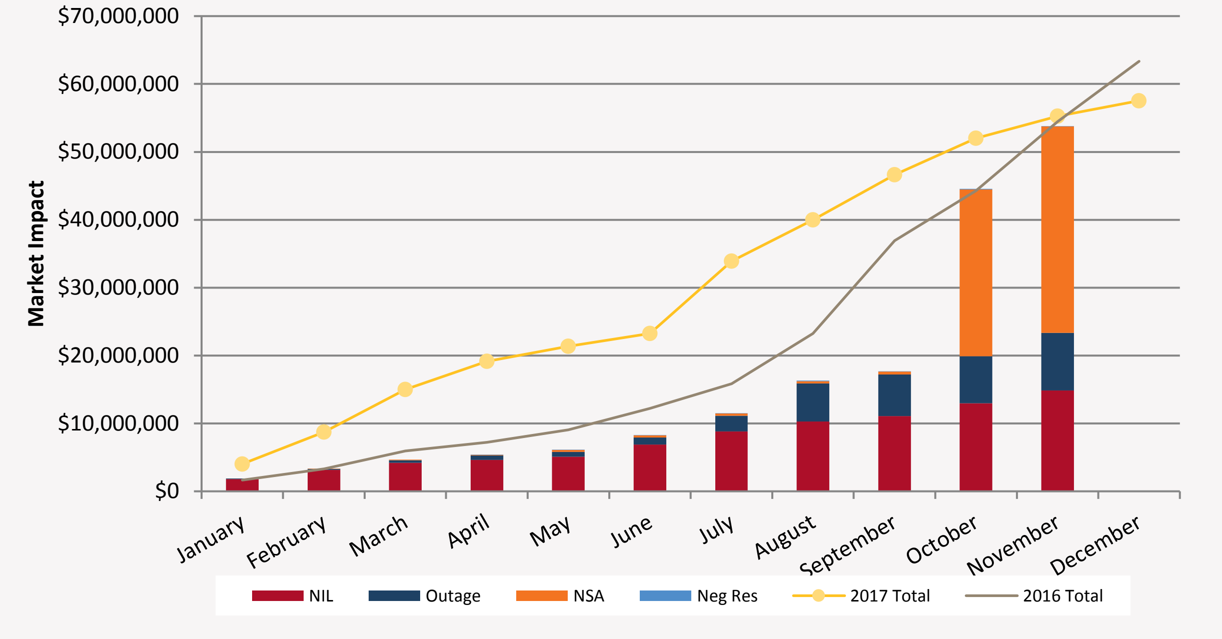
Figure 3 Binding by limit type



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	231	397,600% (92.14)	2,457% (30.58)
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	27	4,924% (110.28)	801% (49.37)
S_NIL_STRENGTH_1	Upper limit of 1295 MW for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required combination is online.	78	841% (9,000)	39.63% (838)
T^V_HAPM_220_1	Out = Hadspen to Palmerston 220 kV line, prevent voltage collapse at George Town 220 kV bus for loss of parallel Hadspen to Palmerston 220 kV line	73	159% (117.84)	33.46% (36.28)
T::T_HA_GT_PM_4	Out = Hadspen to George Town or Hadspen to Palmerston 220 kV line, prevent poorly damped TAS North - South oscillations following fault and trip of Palmerston to Sheffield 220 kV line, Tamar CCGT out of service.	48	155% (170.15)	59.22% (86.03)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
S>SE6161_SETX2_SGBL	Out= South East 132kV CB6161, avoid O/L Snuggery-Blanche 132kV line on trip of South East 132/275 TX2 (this offloads Mayura-South East T 132kV line), Feedback	127	123.44% (76.98)	43.17% (25.33)
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	23	100.% (35.)	51.83% (16.05)
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.	9	89.83% (123.45)	49.01% (83.74)
N>N-NIL_LSDU	Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6), Feedback	62	86.52% (39.63)	24.26% (13.68)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	377	85.98% (205.19)	32.18% (86.7)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N^N-LS_SVC, V^SML_HORC_3, S_NIL_STRENGTH_1, T^V_HAPM_220_1, T::T_HA_GT_PM_4, S>SE6161_SETX2_SGBL: Investigated and no improvement can be made to the constraint equations at this stage.

NSA_Q_BARCALDN: Investigated and the PD formulation will be changed to improve its performance

N>N-NIL_LSDU: Investigated and the mismatch is due to modelling of DFS and SCADA value on Terranora load. DFS forecasting is being investigated to improve its performance. No improvements can be made to the constraint equation 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 November 2018.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Ballarat Battery (Generation Component)	6 November 2018	VIC1	New Generator
Ballarat Battery (Load Component)	6 November 2018	VIC1	New Generator
Wemen Solar Farm	6 November 2018	VIC1	New Generator
Crowlands Wind Farm	6 November 2018	VIC1	New Generator
Gannawarra Battery (Load Component)	7 November 2018	VIC1	New Generator
Gannawarra Battery (Generation Component)	7 November 2018	VIC1	New Generator

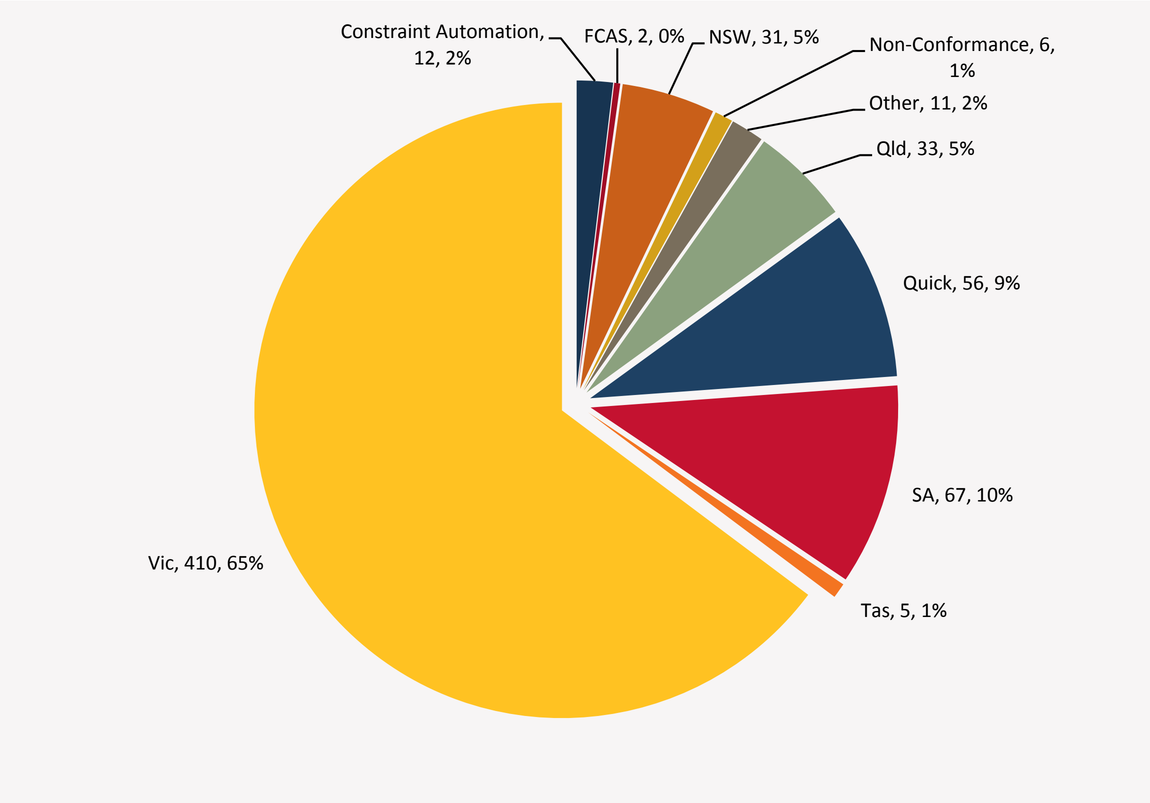
3.1 Constraint Equation Changes

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