AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

September 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 September 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
T>T_LIPM_110_2B	Out= either Liapootah - Waddamana (tee) - Palmerston 220 kV line, avoid O/L Palmerston to Waddamana 110 line (flow to North) on trip of the remaining Liapootah to Waddamana (tee) to Palmerston 220 kV line, feedback	1549 (129.08)	16/06/2016
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	1005 (83.75)	27/08/2018
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.	965 (80.41)	18/09/2018
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	810 (67.5)	04/09/2018
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	650 (54.16)	25/11/2013
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	466 (38.83)	21/08/2013
VSML_ZERO	Vic to SA on ML upper transfer limit of 0 MW	439 (36.58)	21/08/2013
T^V_NIL_8	Out = Nil, Tamar Valley Combined Cycle GT OOS, prevent voltage collapse at Georgetown 220 kV bus for loss of a Sheffield to George Town 220 kV line, considering action of GTRSPS, swamped if TVCC in service	437 (36.41)	31/05/2018

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	427 (35.58)	13/09/2016
S>RBTX2_RBTX1_WEMWP4	Out= Robertstown 275/132kV TX2, avoid O/L Waterloo East-MWP4-Roberstown 132kV line on trip of Robertstown 275/132kV TX1, Feedback	406 (33.83)	14/09/2018

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
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.	1,037,407	18/09/2018
T>>T_PMSH_EXP_3C	Out = Palmerston to Sheffield 220 kV line, avoid O/L Sheffield to George Town 220 kV line (flow to George Town) for trip of other Sheffield to George Town 220 kV line considering NCSPS action, ensure Basslink can compensate NCSPS action.	183,235	26/09/2018
F_MAIN++NIL_MG_R6	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	108,811	21/08/2013
F_MAIN++NIL_MG_R5	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	85,041	21/08/2013
F_I+NIL_MG_R5	Out = Nil, Raise 5 min requirement for a NEM Generation Event	85,013	21/08/2013
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	77,793	08/11/2017
T>T_LIPM_110_2B	Out= either Liapootah - Waddamana (tee) - Palmerston 220 kV line, avoid O/L Palmerston to Waddamana 110 line (flow to North) on trip of the remaining Liapootah to Waddamana (tee) to Palmerston 220 kV line, feedback	73,060	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.

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Change Date
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	62,119	04/05/2018
F_MAIN++NIL_MG_R60	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	61,446	21/08/2013
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	56,333	04/09/2018

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
T>>T_PMSH_EXP_3C	Out = Palmerston to Sheffield 220 kV line, avoid O/L Sheffield to George Town 220 kV line (flow to George Town) for trip of other Sheffield to George Town 220 kV line considering NCSPS action, ensure Basslink can compensate NCSPS action.	20 (1.66)	26/09/2018
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	16 (1.33)	27/08/2018
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	11 (0.91)	02/12/2016
T>T_LIPM_110_2B	Out= either Liapootah - Waddamana (tee) - Palmerston 220 kV line, avoid O/L Palmerston to Waddamana 110 line (flow to North) on trip of the remaining Liapootah to Waddamana (tee) to Palmerston 220 kV line, feedback	5 (0.41)	16/06/2016
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	5 (0.41)	06/05/2015
F_Q++BCDM_L5	Out = Bulli Creek to Dumaresq (8L or 8M) or Dumaresq to Sapphire (8J) line, Qld Lower 5 min Requirement	2 (0.16)	26/04/2018
F_Q++BCDM_L6	Out = Bulli Creek to Dumaresq (8L or 8M) or Dumaresq to Sapphire (8J) line, Qld Lower 6 sec Requirement	1 (0.08)	26/04/2018
F_Q++BCDM_L60	Out = Bulli Creek to Dumaresq (8L or 8M) or Dumaresq to Sapphire (8J) line, Qld Lower 60 sec Requirement	1 (0.08)	26/04/2018
F_T+LREG_0050	Tasmania Lower Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	1 (0.08)	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	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
T>>T_PMSH_EXP_3C	Constraint equation violated for 20 non-consecutive DIs during the month. Max violation of 44.2 MW occurred on 25/09/2018 at 1415 hrs. Constraint equation violated due to the Basslink Interconnector being limited by its export ramp down rate.
N^N-LS_SVC	Constraint equation violated for 16 DIs during the month, 7 of which were consecutive. Max violation of 13.35 MW occurred on 25/09/2018 at 1730 hrs. Constraint equation violated due to competing requirement with the Terranora Interconnector import limit set by N_MBTE1_B.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 11 non-consecutive DIs on 28/09/2018. Max violation of 14.82 MW occurred on 28/09/2018 at 0145 hrs. Constraint equation violated due to Tasmania raise 6 second availability less than the requirement.
T>T_LIPM_110_2B	Constraint equation violated for 5 DIs during the month. Max violation of 75.17 MW occurred on 06/09/2018 at 0210 hrs. Constraint equation violated due to multiple Tasmanian hydro generating units being limited by their ramp down rates. These include Gordon, Meadowbank, and the aggregated Liapootah, Catagunya and Wayatinah units.
NSA_Q_BARCALDN	Constraint equation violated for 5 DIs on 16/09/2018. Max violation of 15 MW occurred on 16/09/2018 at 1605 hrs. Constraint equation violated due to the Barcaldine GT being limited by its start-up profile and availability.
F_Q++BCDM_L5	Constraint equation violated for 2 DIs on 07/09/2018 at 2210 hrs and 26/09/2018 at 0110 hrs. Max violation of 200.58 MW occurred on 26/09/2018 at 0110 hrs. Constraint equation violated due to Queensland lower 5 minute service availability less than the requirement.
F_Q++BCDM_L6	Constraint equation violated for 1 DI on 26/09/2018 at 0110 hrs with a violation degree of 105.41 MW. Constraint equation violated due to Queensland lower 6 second service availability less than the requirement.
F_Q++BCDM_L60	Constraint equation violated for 1 DI on 26/09/2018 at 0110 hrs with a violation degree of 72.06 MW. Constraint equation violated due to Queensland lower 60 second service availability less than the requirement.
F_T+LREG_0050	Constraint equation violated for 1 DI on 19/09/2018 at 1500 hrs with a violation degree of 50 MW. Constraint equation violated due to Tasmania lower regulation availability less than the requirement.
F_T+NIL_WF_TG_R6	Constraint equation violated for 1 DI on 28/09/2018 at 1520 hrs with a violation degree of 18.13 MW. Constraint equation violated due to Tasmania raise 6 second service availability less than the requirement.

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_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslinkable transfer FCAS	1297 (108.08)	420.32 (478.0)

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	1159 (96.58)	329.54 (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	1005 (83.75)	360.01 (478.0)
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	1005 (83.75)	-50.16 (74.16)
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	810 (67.5)	-300.69 (-597.46)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	650 (54.17)	-73.71 (-97.0)
F_T++NIL_ML_L6	T-V-MNSP1 Export	Out = Nil, Lower 6 sec requirement for a Tasmania Load Event, Basslink able to transfer FCAS, reduce by very fast response on Basslink	603 (50.25)	467.1 (478.0)
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	562 (46.83)	149.56 (51.98)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	462 (38.5)	0.0 (0.0)
VSML_ZERO	V-S-MNSP1 Export	Vic to SA on ML upper transfer limit of 0 MW	430 (35.83)	0.0 (0.0)

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

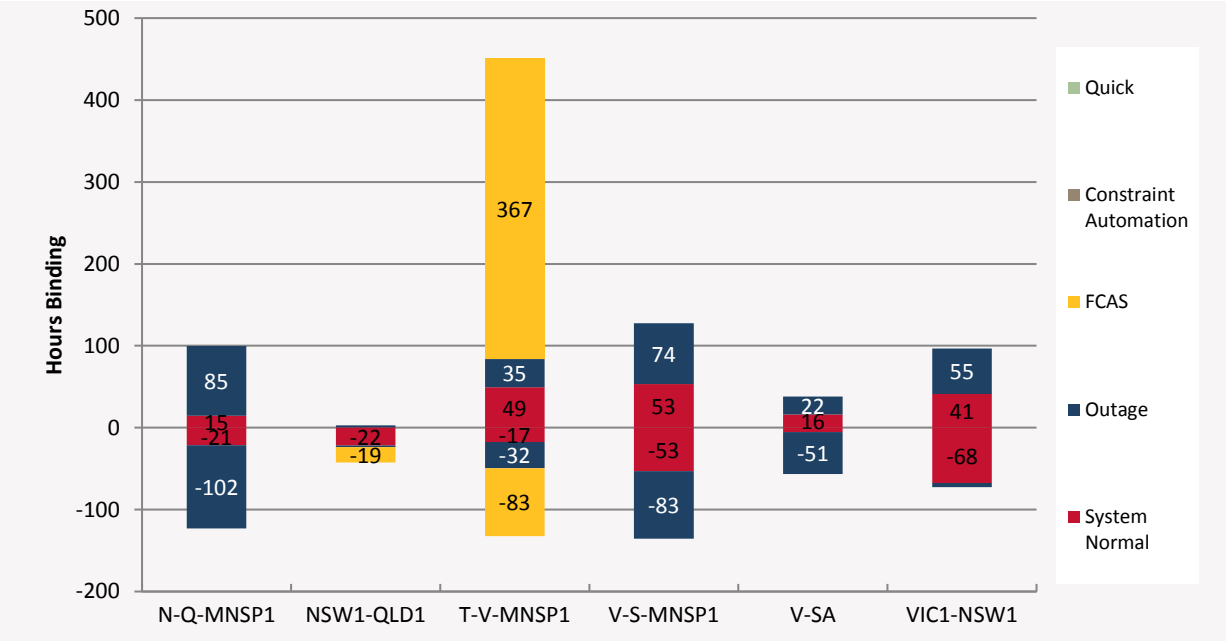
Non-real time constraint automation was not used.

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.

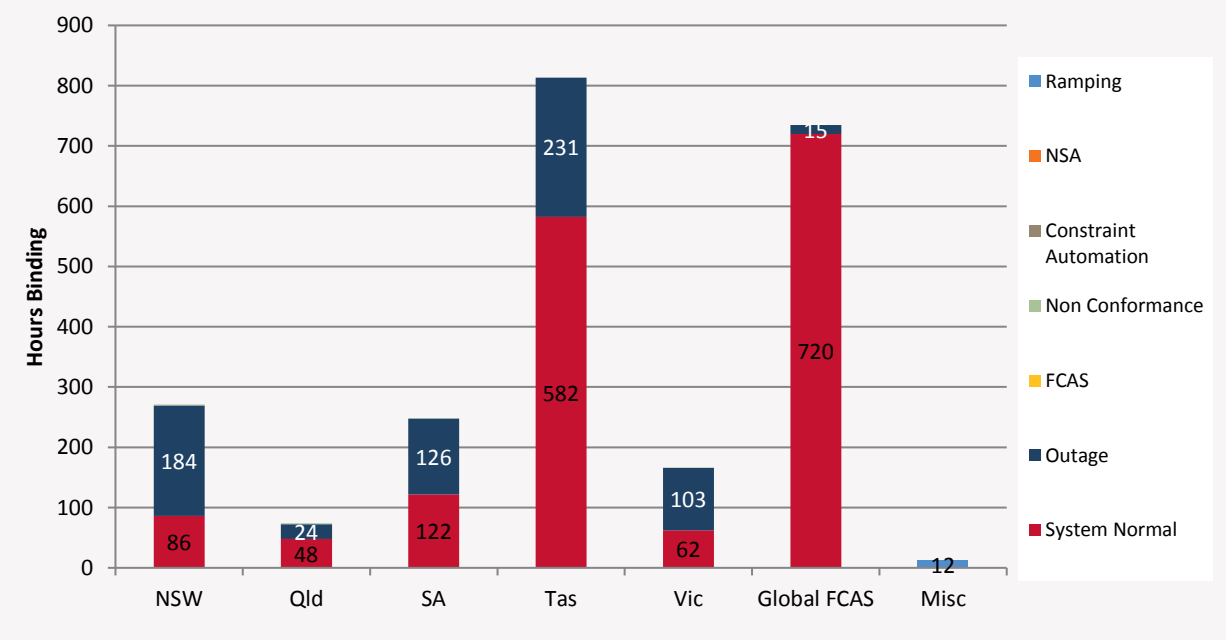
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

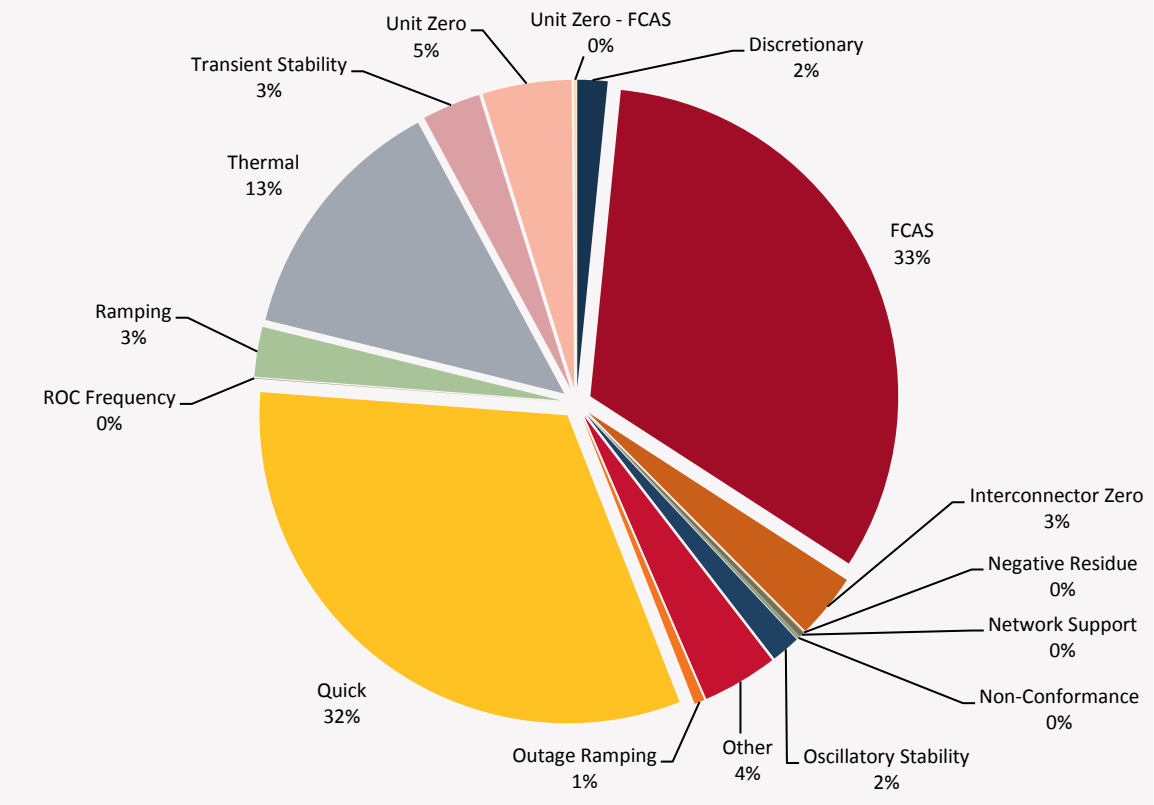
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

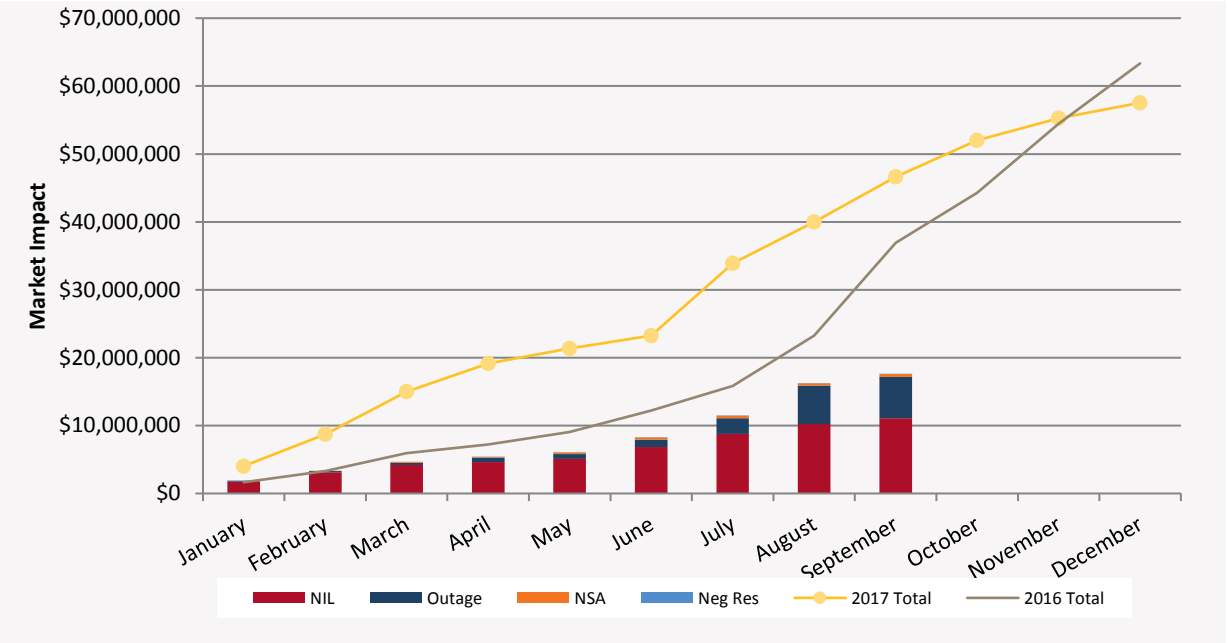
Figure 3 Binding by limit type



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	207	6,275% (108.11)	236% (32.54)
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	30	3,787% (152.52)	649% (73.34)
T^^V_PMSH_1	Out = Palmerston to Sheffield 220 kV line, prevent voltage collapse at Georgetown 220 kV bus for loss of either one Sheffield to Georgetown 220kV line or one Hadspen to Georgetown 220kV line.	76	1,251% (288.83)	133.33% (96.25)
V::N_WBHO_V2	Out = Waubra to Ararat or Horsham to Ararat 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	23	707% (292.01)	90.95% (99.37)
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.	19	326% (175.18)	41.41% (64.94)
V::N_HWSM_V1	Out = Hazelwood to South Morang OR Hazelwood to Rowville 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	7	242% (123.74)	89.98% (52.34)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V>SMLARHO1	Out = Ararat to Crowlands or Crowlands to Horsham 220kV line, avoid O/L or voltage collapse on Buronga to Balranald to Darlington Point (X5) line for trip of Bendigo to Kerang 220kV line	7	191% (21.79)	59.8% (10.07)
V::N_HORC_V2	Out = Horsham to Red Cliffs 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	12	191% (112.63)	59.66% (65.47)
V::N_WBHO_S2	Out = Waubra to Ararat or Horsham to Ararat 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	5	154% (42.71)	41.93% (35.76)
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.	20	134.88% (589)	89.96% (355.22)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^SML_HORC_3: Investigated and no improvement can be made to the constraint equation at this stage.

T^^V_PMSH_1: Investigated and no improvement can be made to the constraint equation at this stage.

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

V::N_WBHO_V2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_NIL_V2: Investigated and no improvement can be made to the constraint equation at this stage

V::N_HORC_V2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_WBHO_S2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_NIL_S2: Investigated and 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 July 2018.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Emerald Solar Farm	13 September 2018	QLD	New Generator
Hayman Solar Farm	28 September 2018	QLD	New Generator
Daydream Solar Farm	28 September 2018	QLD	New Generator
Coleambally Solar Farm	3 September 2018	NSW	New Generator
South Morang H3 Transformer	15 September 2018	Victoria	South Morang Terminal Station H3 330 kV/220 kV transformer commissioned
Crowlands No.2 220 kV Bus	15 September 2018	Victoria	Crowlands Terminal Station No.2 220 kV bus commissioned

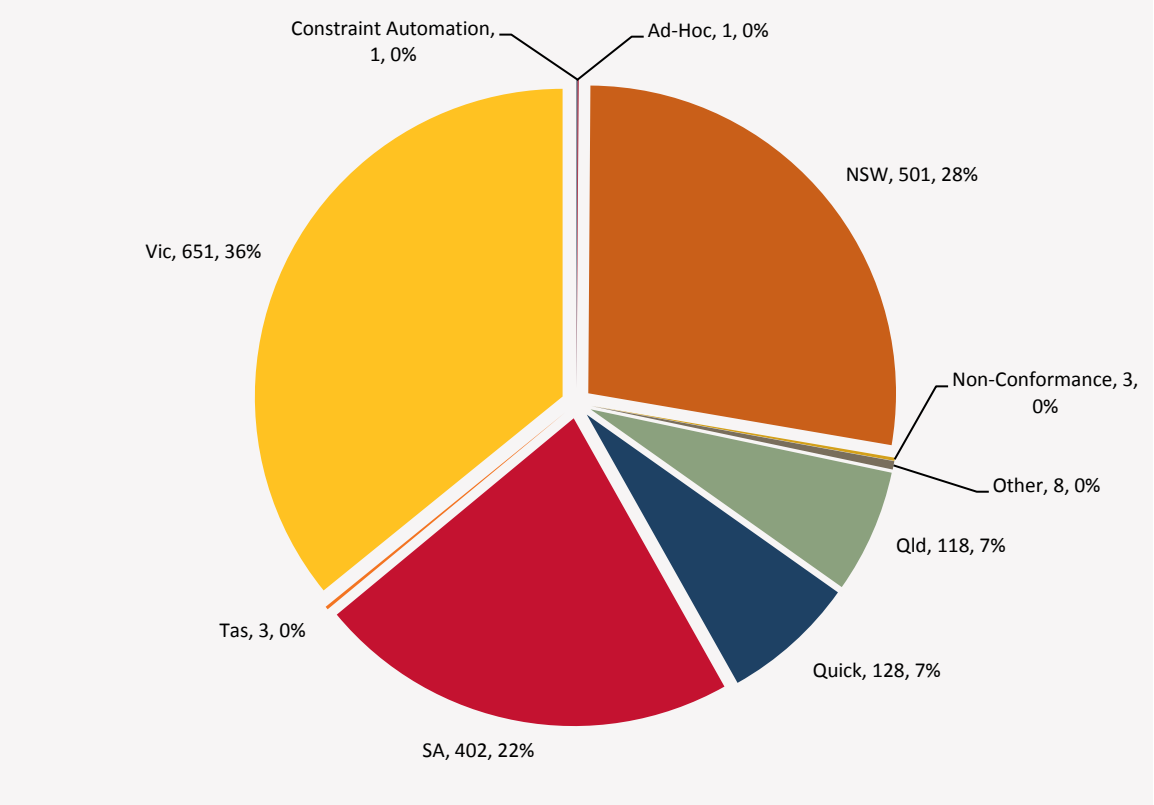
3.1 Constraint Equation Changes

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