AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

July 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 July 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
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.	2836 (236.33)	13/07/2018
V::S_SETB_TBSE_2	Out= one South East to Tailem Bend 275kV line (NOTE: with both Black Range series capacitors O/S or I/S); Vic to SA Transient Stability limit for loss of one of the Tailembend-South East 275kV lines (South East Capacitor Available).	1639 (136.58)	14/02/2017
V::S_SETB_MAXG_2	Out= one South East to Tailem Bend 275kV line; Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available). (NOTE: with both Black Range series capacitors O/S).	969 (80.75)	31/10/2016
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	961 (80.08)	13/09/2016
S::V_TBSE_TBSE_2	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps O/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	910 (75.83)	11/04/2017
V>>V_NIL_2A_R	Out = Nil, avoid pre-contingent O/L of South Morang F2 500/330kV transformer, radial mode, YWPS unit 1 on 500kV, feedback	783 (65.25)	16/07/2018
NQTE_BLOCK_ECS	Minimum of 29MW on Directlink QLD to NSW to ensure that Directlink ECS will not operate when Directlink support is required	645 (53.75)	04/06/2018

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	386 (32.16)	06/08/2018
V^^S_SETB_TBSE_2	Out= one South East to Tailem Bend 275kV line (NOTE: with both Black Range series capacitors O/S or I/S); Vic to SA Long Term Voltage Stability limit for loss of one of the Tailembend-South East 275kV lines (South East Capacitor Available).	374 (31.16)	14/02/2017
S_SNOW_N+S_190	Discretionary upper limit for Snowtown North and South Windfarms of 190 MW	360 (30.0)	24/07/2018

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.	2,992,844	13/07/2018
V::S_SETB_TBSE_2	Out= one South East to Tailem Bend 275kV line (NOTE: with both Black Range series capacitors O/S or I/S); Vic to SA Transient Stability limit for loss of one of the Tailembend-South East 275kV lines (South East Capacitor Available).	327,553	14/02/2017
F_S+RREG_0035	SA Raise Regulation FCAS Requirement greater than 35 MW	324,852	08/01/2015
F_S+LREG_0035	SA Lower Regulation FCAS Requirement greater than 35 MW	298,248	08/01/2015
V>SMLARHO1	Out = Ararat 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	268,388	02/07/2018
S::V_TBSE_TBSE_2	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps O/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	196,992	11/04/2017

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
S^NIL_PL_MAX	Out = Nil, Maximum generation at Port Lincoln Due to voltage stability limit.	184,394	11/07/2017
V::S_SETB_MAXG_2	Out= one South East to Tailem Bend 275kV line; Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available). (NOTE: with both Black Range series capacitors O/S).	183,739	31/10/2016
S_LB_1+2+3_190	Discretionary upper limit for Lake Bonney 1 + 2+ 3 Windfarms<= 190 MW	183,476	24/07/2018
S_SNOW_N+S_190	Discretionary upper limit for Snowtown North and South Windfarms of 190 MW	117,788	24/07/2018

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
V::S_SETB_MAXG_2	Out= one South East to Tailem Bend 275kV line; Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available). (NOTE: with both Black Range series capacitors O/S).	80 (6.66)	31/10/2016
S::V_TBSE_TBSE_2	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps O/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	42 (3.5)	11/04/2017
NRM_SA1_VIC1	Negative Residue Management constraint for SA to VIC flow	6 (0.5)	12/06/2012
F_T++NIL_WF_TG_R5	Out= Nil, Tasmania Raise 5 min 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	6 (0.5)	12/04/2016
S_LB_1+2+3_190	Discretionary upper limit for Lake Bonney 1 + 2+ 3 Windfarms<= 190 MW	6 (0.5)	24/07/2018
NSA_V_BDL01_20	Bairnsdale Unit 1 >= 20 MW for Network Support Agreement	5 (0.41)	21/08/2013
NSA_V_BDL02_20	Bairnsdale Unit 2 >= 20 MW for Network Support Agreement	4 (0.33)	21/08/2013
V_MTGBRAND_11WT	Limit number of turbine online for Mt Gelibrand WF to be not exceed 11	4 (0.33)	20/06/2018
F_T++NIL_MG_RECL_R5	Out = Nil, Raise 5 min requirement for a Tasmania Reclassified Woolnorth Generation Event, Basslink able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	2 (0.16)	02/12/2016
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	2 (0.16)	30/04/2018

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
V::S_SETB_MAXG_2	Constraint equation violated for 80 DIs during the month, including multiple instances where the constraint violated for 6 or more consecutive DIs. Max violation of 71.05 MW occurred on 23/07/2018 at 0020 hrs. Constraint equation violated due to competing requirement with the Heywood Interconnector import limit set by S::V_TBSE_TBSE_2.
S::V_TBSE_TBSE_2	Constraint equation violated for 42 DIs during the month, including multiple instances where the constraint violated for 6 or more consecutive DIs. Max violation of 56.45 MW occurred on 23/07/2018 at 0000 hrs. Constraint equation violated due to competing requirement with the Heywood Interconnector export limit set by V::N_SETB_V1.
NRM_SA1_VIC1	Constraint equation violated for 6 non-consecutive DIs on 23/07/2018. Max violation of 75.28 MW occurred on 23/07/2018 at 0035 hrs. Constraint equation violated due to competing requirement with the Heywood Interconnector and Murraylink export limits set by V::S_SETB_MAXG_2 and V^SML_NSWRB_2 respectively.
F_T++NIL_WF_TG_R5	Constraint equation violated for 6 non-consecutive DIs during the month. Max violation of 16.62 MW occurred on 08/07/2018 at 0355 hrs. Constraint equation violated due to Tasmania raise 5 minute service availability less than the requirement.
S_LB_1+2+3_190	Constraint equation violated for 6 DIs during the month. Max violation of 9.04 MW occurred on 31/07/2018 at 1500 hrs. Constraint equation violated due to Lake Bonney 2 and 3 being limited by their ramp down rates.
NSA_V_BDL01_20	Constraint equation violated for 5 DIs during the month, with a violation degree of 20 MW for each DI. Constraint equation violated due to the Bairnsdale unit 1 being limited by its start-up profile.
NSA_V_BDL02_20	Constraint equation violated for 4 DIs on 09/07/2018, with a violation degree of 20 MW for each DI. Constraint equation violated due to the Bairnsdale unit 2 being limited by its start-up profile.
V_MTGBRAND_11WT	Constraint equation violated for 4 DIs during the month. Max violation of 12.87 MW occurred on 15/07/2018 at 1210 hrs. Constraint equation violated due to technical issues with Mt. Gellibrand wind farm which resulted in the wind farm not following its dispatch target. The technical issues have been fixed.
F_T++NIL_MG_RECL_R5	Constraint equation violated for 2 DIs on 07/07/2018 at 1600 hrs and 1605 hrs. Max violation of 24.8 MW occurred on 07/07/2018 at 1600 hrs. Constraint equation violated due to Tasmania raise 5 minute service availability less than the requirement.
F_T_NIL_MINP_R6	Constraint equation violated for 2 DIs on 07/07/2018 at 1600 hrs and on 08/07/2018 at 0815 hrs. Max violation of 11.86 MW occurred on 07/07/2018 at 1600 hrs. 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)
V::S_SETB_TBSE_2	V-SA Export	Out= one South East to Tailem Bend 275kV line (NOTE: with both Black Range series capacitors O/S or I/S); Vic to SA Transient Stability limit for loss	1537	29.17

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
		of one of the Tailembend-South East 275kV lines (South East Capacitor Available).	(128.08)	(133.38)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1360 (113.33)	413.43 (478.0)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1200 (100.0)	437.62 (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	1113 (92.75)	395.86 (478.0)
S>V_NIL_NIL_RBNW	V-S-MNSP1 Import	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	961 (80.08)	-166.31 (-192.48)
S::V_TBSE_TBSE_2	V-SA Import	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps O/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	893 (74.42)	-143.6 (-361.83)
V::S_SETB_MAXG_2	V-SA Export	Out= one South East to Tailem Bend 275kV line; Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available). (NOTE: with both Black Range series capacitors O/S).	867 (72.25)	-143.16 (29.17)
V>>V_NIL_2A_R	V-SA Import	Out = Nil, avoid pre-contingent O/L of South Morang F2 500/330kV transformer, radial mode, YWPS unit 1 on 500kV, feedback	770 (64.17)	-94.99 (-274.88)
V>>V_NIL_2A_R	VIC1-NSW1 Export	Out = Nil, avoid pre-contingent O/L of South Morang F2 500/330kV transformer, radial mode, YWPS unit 1 on 500kV, feedback	764 (63.67)	1079.76 (1350.04)
V>>V_NIL_2A_R	V-S-MNSP1 Export	Out = Nil, avoid pre-contingent O/L of South Morang F2 500/330kV transformer, radial mode, YWPS unit 1 on 500kV, feedback	758 (63.17)	-146.8 (33.45)

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

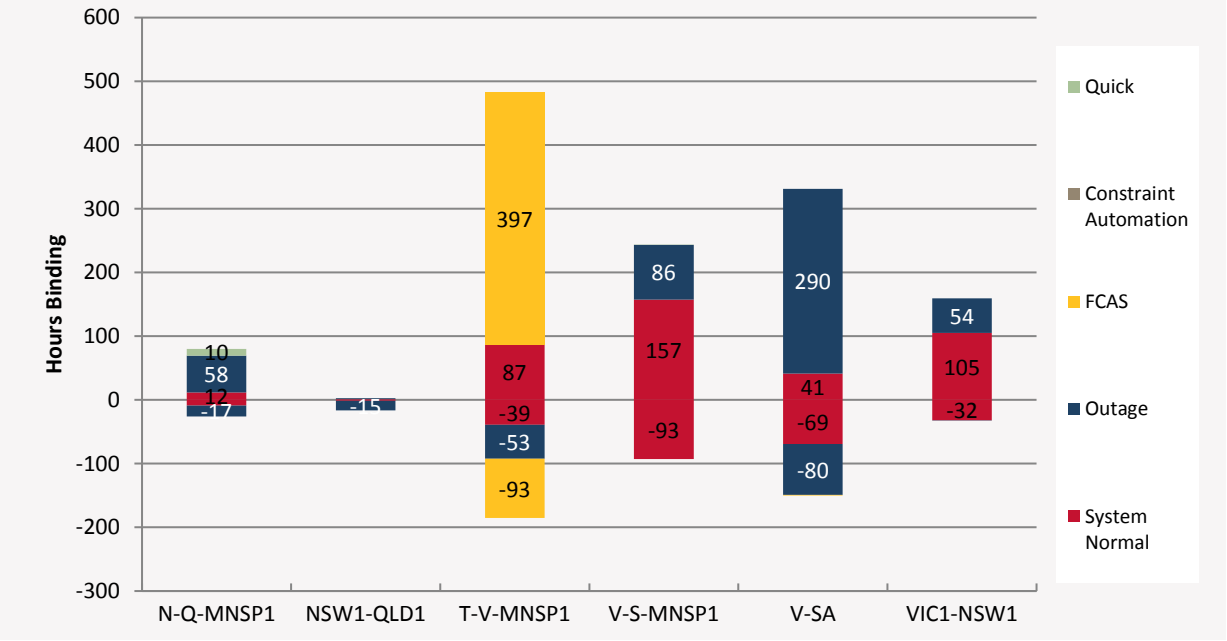
Non-real time constraint automation was not used.

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.

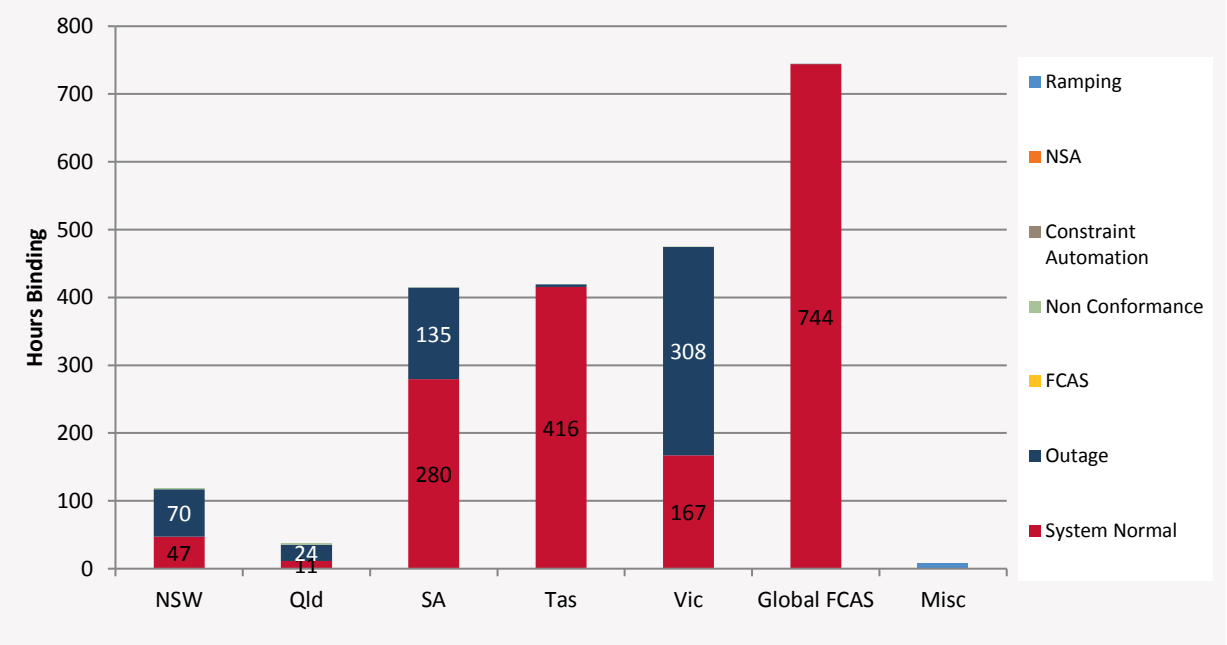
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

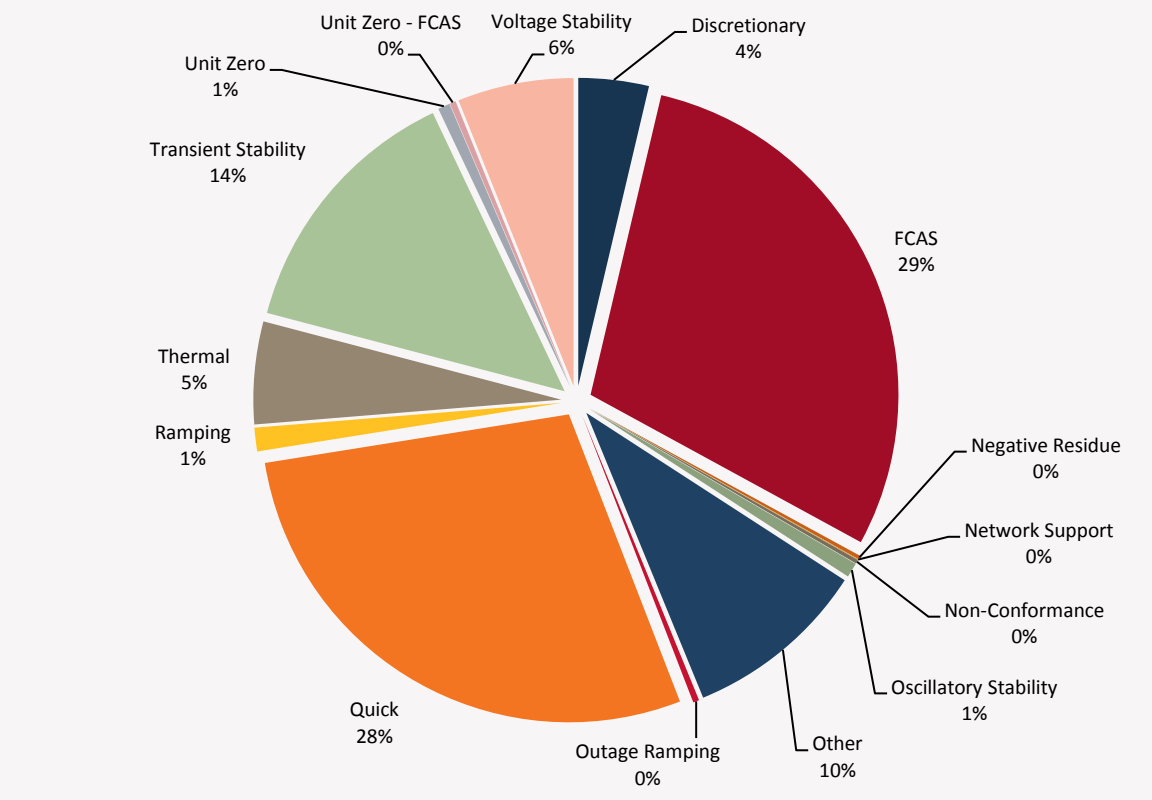
Figure 2 Regional binding dispatch hours



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.

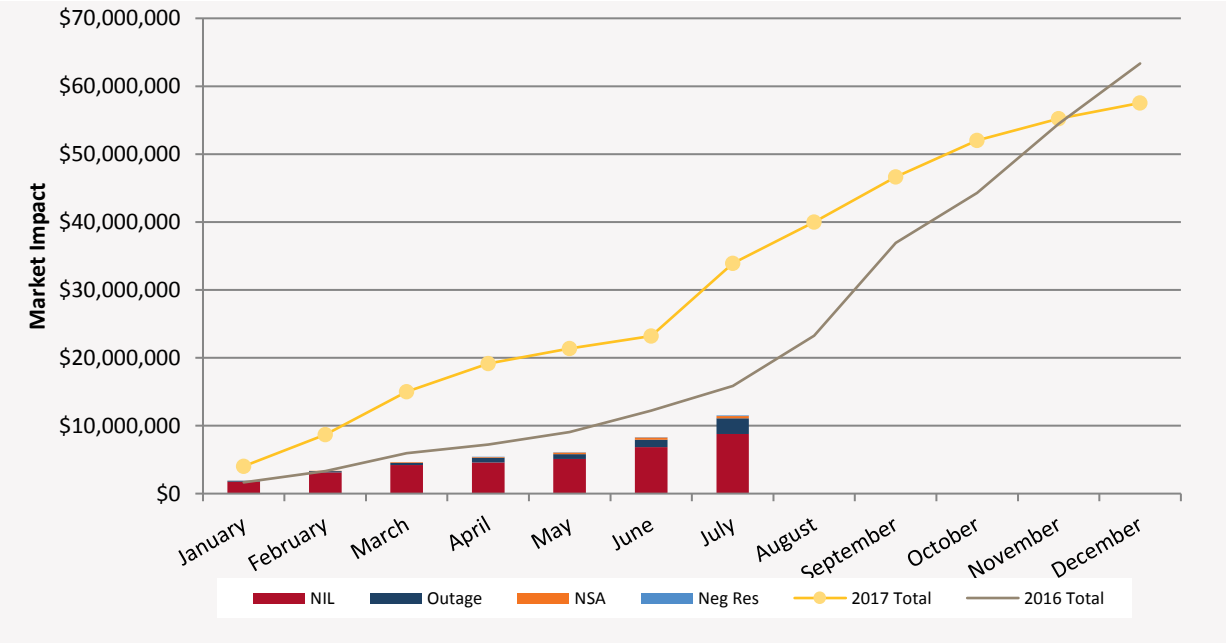
Figure 3 Binding by limit type



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
V::S_SETB_MAXG_2	Out= one South East to Tailem Bend 275kV line; Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available). (NOTE: with both Black Range series capacitors O/S).	263	52,882% (218.47)	338% (40.63)
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.	96	10,078% (231.88)	123.38% (55.09)
V>SMLARHO1	Out = Ararat 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	69	6,335% (109.85)	388% (39.72)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_SETB_V1	Out = one South East to Tailem Bend 275kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	27	4,378% (226.98)	458% (91.71)
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.	41	1,160% (281.4)	88.% (66.4)
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.	488	876% (9,024)	9.05% (470.92)
V::N_SETB_V2	Out = one South East to Tailem Bend 275kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	124	872% (353.61)	74.99% (88.)
V::N_SETB_S2	Out = one South East to Tailem Bend 275kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	19	769% (202.21)	92.19% (56.08)
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	9	767% (67.61)	256% (30.69)
S::V_TBSE_TBSE_2	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps O/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	182	736% (65.41)	29.1% (13.17)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_SETB_V2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_SETB_S2: Investigated and no improvement can be made to the constraint equation at this stage.

V::S_SETB_MAXG_2: 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>SMLARHO1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_SETB_V1: 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.

S_NIL_STRENGTH_1: Investigated. Mismatch was due to differences in generator targets 4 hours in the future compared to targets in dispatch. No improvement can be made to the constraint equation at this stage.

S::V_TBSE_TBSE_2: 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
Bodangora Wind Farm	10 July 2018	NSW	New Generator
Bannerton Solar Farm	11 July 2018	VIC	New Generator
Willogoleche Wind Farm	24 July 2018	SA	New Generator
Collinsville Solar Farm	31 July 2018	QLD	New Generator
Bungala Stage 2 Solar PV	31 July 2018	SA	New Generator

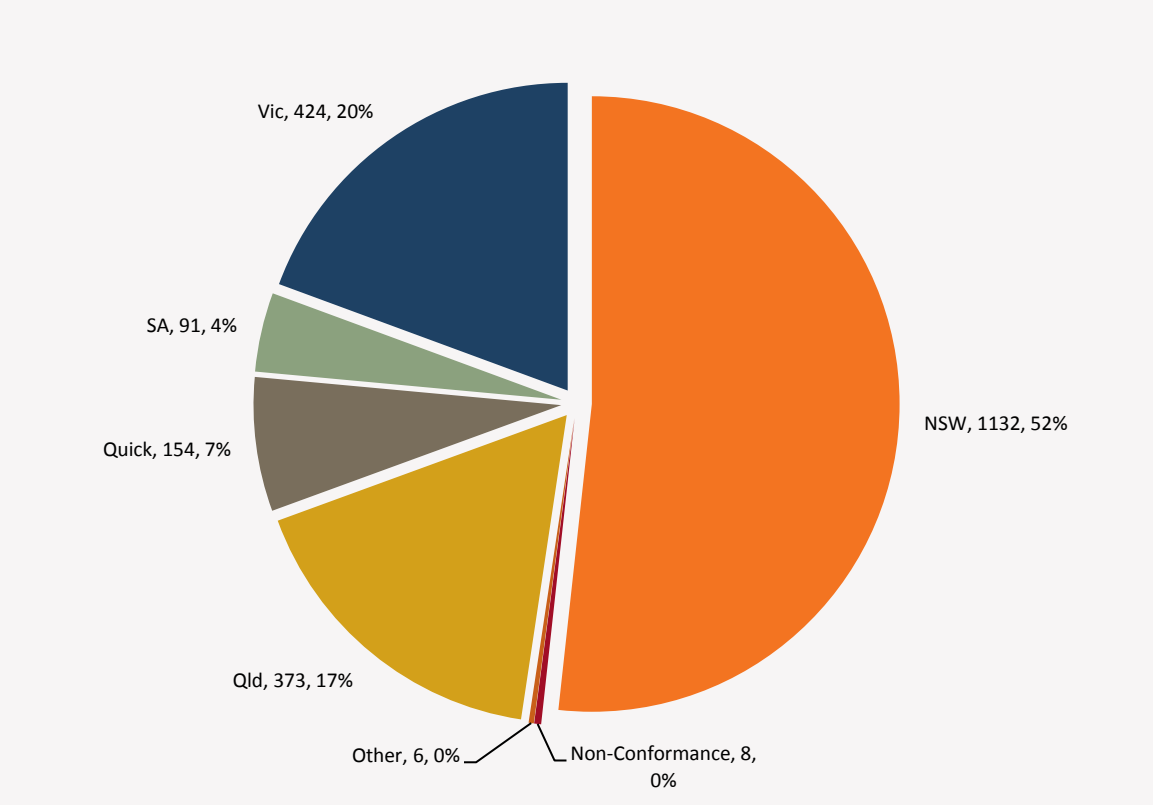
3.1 Constraint Equation Changes

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