AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

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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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Contents

Tables

Figures

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.	2935 (244.58)	24/08/2018
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	1511 (125.91)	13/09/2016
S_SNOW_N+S_190	Discretionary upper limit for Snowtown North and South Windfarms of 190 MW	1093 (91.08)	07/08/2018
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	977 (81.41)	03/09/2018
Q>NIL_BI_FB	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104 and 7105 (T022 Callide A to T152 Gladstone South) 132 kV lines open with 132 kV intact between T022 Callide A and H015 Lilyvale.	760 (63.33)	05/09/2016
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	549 (45.75)	27/08/2018
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.	524 (43.66)	07/08/2018
S_LB_1+2+3_190	Discretionary upper limit for Lake Bonney 1 + 2+ 3 Windfarms<= 190 MW	510 (42.5)	07/08/2018

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
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.	419 (34.91)	27/08/2018
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).	369 (30.75)	07/08/2018

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.	3,075,095	24/08/2018
S_SNOW_N+S_190	Discretionary upper limit for Snowtown North and South Windfarms of 190 MW	649,770	07/08/2018
F_Q+ML_L60_0400	Lower 60 sec Service Requirement for Qld Load Event, ML = 390	241,293	21/08/2013
S_LB_1+2+3_190	Discretionary upper limit for Lake Bonney 1 + 2+ 3 Windfarms<= 190 MW	218,633	07/08/2018
S_PW-CB6156_LG1	Out=Penola West 132kV CB 6156 O/S (Note: with Penola West 132kV CB 6158 CLOSED), Oscillatory stability limit Ladbroke Grove 1 can generate up to 40MW on a single unit OR 20MW max per unit (40MW total output)	201,980	02/06/2017
S_SNOWNTH1_ZERO	Discretionary upper limit for Snowtown 2 North WF generation of 0 MW	196,623	07/08/2018
S_SNOWSTH1_ZERO	Discretionary upper limit for Snowtown 2 South WF generation of 0 MW	181,024	07/08/2018
F_Q+ML_L5_0400	Lower 5 min Service Requirement for Qld Load Event, ML = 390	173,400	21/08/2013
F_Q+ML_L6_0400	Lower 6 sec Service Requirement for Qld Load Event, ML = 390	157,334	21/08/2013
N_STWF1_ZERO	Silverton wind farm upper limit of 0 MW	129,074	06/02/2018

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
F_Q+KC_R5	Raise 5 min Service Requirement for Qld Generation Event (Kogan Creek)	17 (1.41)	13/10/2014
F_Q+KC_R6	Raise 6 sec Service Requirement for Qld Generation Event (Kogan Creek)	17 (1.41)	13/10/2014
F_Q+ML_L5_0400	Lower 5 min Service Requirement for Qld Load Event, ML = 390	17 (1.41)	21/08/2013
F_Q+ML_L6_0400	Lower 6 sec Service Requirement for Qld Load Event, ML = 390	17 (1.41)	21/08/2013
F_Q+MM1_R5	Raise 5 min Service Requirement for Qld Generation Event (Millmerran unit 1)	16 (1.33)	13/10/2014
F_Q+ML_L60_0400	Lower 60 sec Service Requirement for Qld Load Event, ML = 390	16 (1.33)	21/08/2013
F_Q+MG_R5	Raise 5 min Service Requirement for Qld Generation Event	16 (1.33)	13/10/2014
F_Q+KC_R60	Raise 60 sec Service Requirement for Qld Generation Event (Kogan Creek)	15 (1.25)	13/10/2014
F_Q+LREG_0110	Qld Lower Regulation Requirement greater than 110 MW	14 (1.16)	21/08/2013
F_Q+TNT_R5	Raise 5 min Service Requirement for Qld Generation Event (Tarong North)	13 (1.08)	13/10/2014

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_Q+KC_R5	Constraint equation violated for 17 consecutive DIs on 25/08/2018 from 1325 to 1445 hrs. Max violation of 478.25 MW occurred at 1325 hrs. Constraint equation violated due to Queensland raise 5 minute service availability less than the requirement for the loss of Kogan Creek Power Station, post Queensland separation event at 1312 hrs.
F_Q+KC_R6	Constraint equation violated for 17 consecutive DIs on 25/08/2018 from 1325 to 1445 hrs. Max violation of 431.21 MW occurred at 1325 hrs. Constraint equation violated due to Queensland raise 6 second service availability less than the requirement for the loss of Kogan Creek Power Station, post Queensland separation event at 1312 hrs.
F_Q+ML_L5_0400	Constraint equation violated for 17 consecutive DIs on 25/08/2018 from 1325 to 1445 hrs. Max violation of 293.94 MW occurred at 1350 hrs. Constraint equation violated due to Queensland lower 5

Constraint Equation ID (System Normal Bold)	Description
	minute service availability less than the requirement for a Queensland load event, post Queensland separation event at 1312 hrs.
F_Q+ML_L6_0400	Constraint equation violated for 17 consecutive DIs on 25/08/2018 from 1325 to 1445 hrs. Max violation of 226.82 MW occurred at 1400 hrs. Constraint equation violated due to Queensland lower 6 second service availability less than the requirement for a Queensland load event, post Queensland separation event at 1312 hrs.
F_Q+MM1_R5	Constraint equation violated for 16 consecutive DIs on 25/08/2018 from 1325 to 1440 hrs. Max violation of 219.58 MW occurred at 1325 hrs. Constraint equation violated due to Queensland raise 5 minute service availability less than the requirement for the loss of Millmerran Power Station Unit 1, post Queensland separation event at 1312 hrs.
F_Q+ML_L60_0400	Constraint equation violated for 16 consecutive DIs on 25/08/2018 from 1325 to 1440 hrs. Max violation of 210.78 MW occurred at 1400 hrs. Constraint equation violated due to Queensland lower 60 second service availability less than the requirement for a Queensland load event, post Queensland separation event at 1312 hrs.
F_Q+MG_R5	Constraint equation violated for 16 consecutive DIs on 25/08/2018 from 1325 to 1440 hrs. Max violation of 146.22 MW occurred at 1345 hrs. Constraint equation violated due to Queensland raise 5 minute service availability less than the requirement for the loss of Queensland's largest generating unit, post Queensland separation event at 1312 hrs.
F_Q+KC_R60	Constraint equation violated for 15 consecutive DIs on 25/08/2018 from 1325 to 1435 hrs. Max violation of 400.18 MW occurred at 1325 hrs. Constraint equation violated due to Queensland raise 60 second service availability less than the requirement for the loss of Kogan Creek Power Station, post Queensland separation event at 1312 hrs.
F_Q+LREG_0110	Constraint equation violated for 14 consecutive DIs on 25/08/2018 from 1325 to 1430 hrs. Max violation of 81.33 MW occurred at 1350 hrs. Constraint equation violated due to Queensland lower regulation service availability less than the requirement, post Queensland separation event at 1312 hrs.
F_Q+TNT_R5	Constraint equation violated for 13 consecutive DIs on 25/08/2018 from 1325 to 1425 hrs. Max violation of 230.32 MW occurred at 1345 hrs. Constraint equation violated due to Queensland raise 5 minute service availability less than the requirement for the loss of Tarong North Power Station, post Queensland separation event at 1312 hrs.

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	2152 (179.33)	449.52 (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	1511 (125.92)	-171.58 (-198.68)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	968 (80.67)	470.4 (478.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
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	962 (80.17)	-113.57 (-494.46)
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	939 (78.25)	-160.21 (57.01)
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	936 (78.0)	1053.92 (1524.55)
V>>V_NIL_2A_R	T-V-MNSP1 Export	Out = Nil, avoid pre-contingent O/L of South Morang F2 500/330kV transformer, radial mode, YWPS unit 1 on 500kV, feedback	900 (75.0)	307.87 (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	860 (71.67)	446.09 (478.0)
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	744 (62.0)	471.84 (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	548 (45.67)	-60.42 (44.58)

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

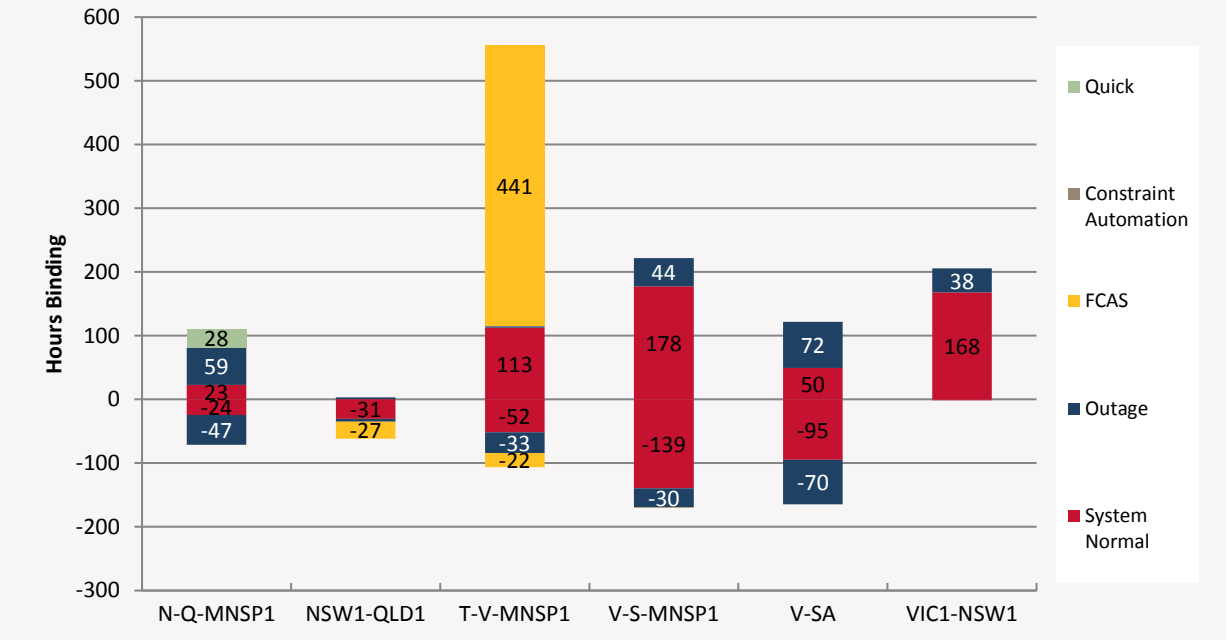
Non-real time constraint automation was not used.

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.

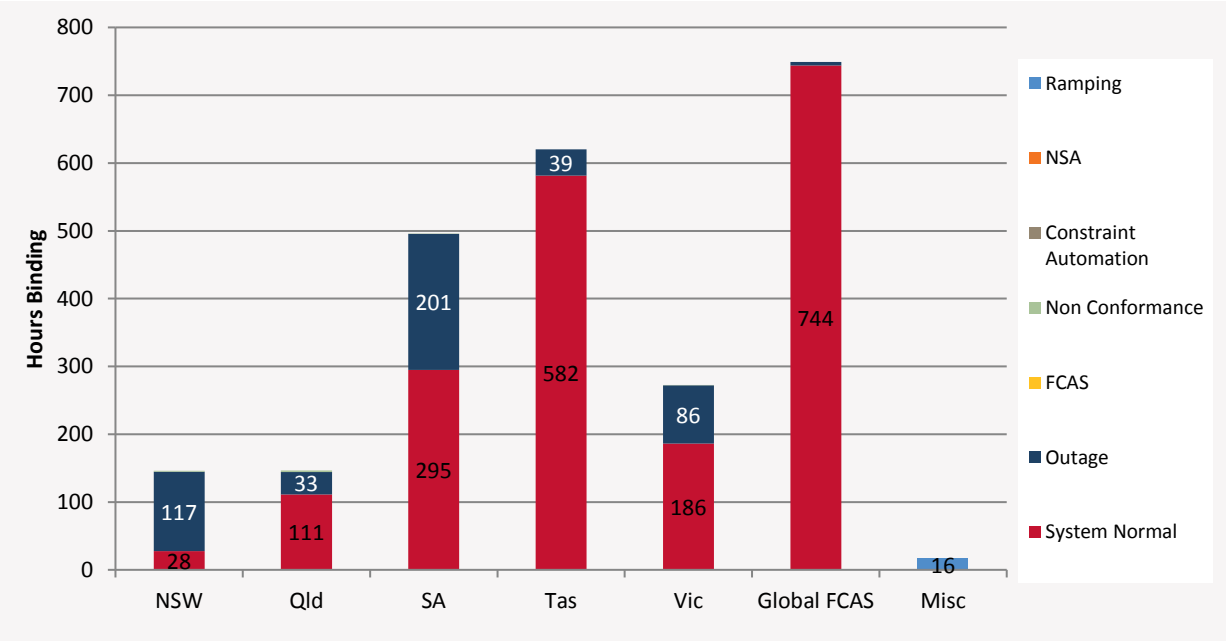
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

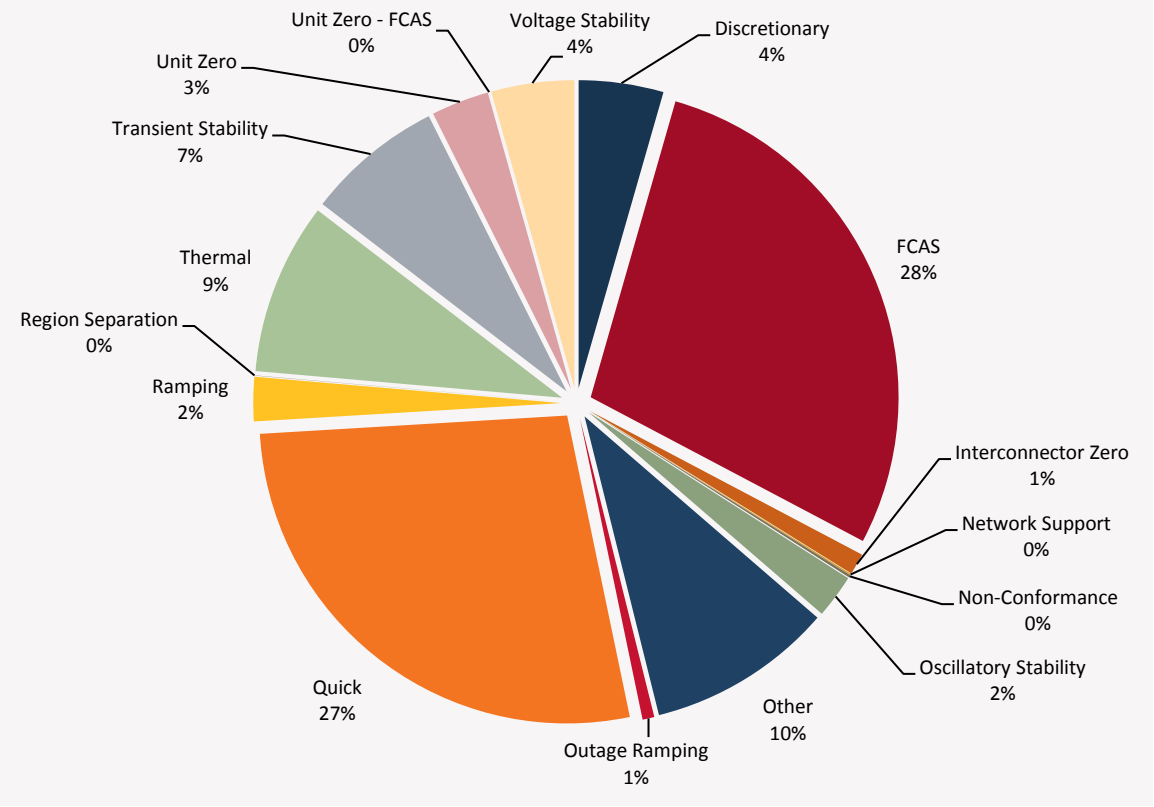
Figure 2 Regional binding dispatch hours



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.

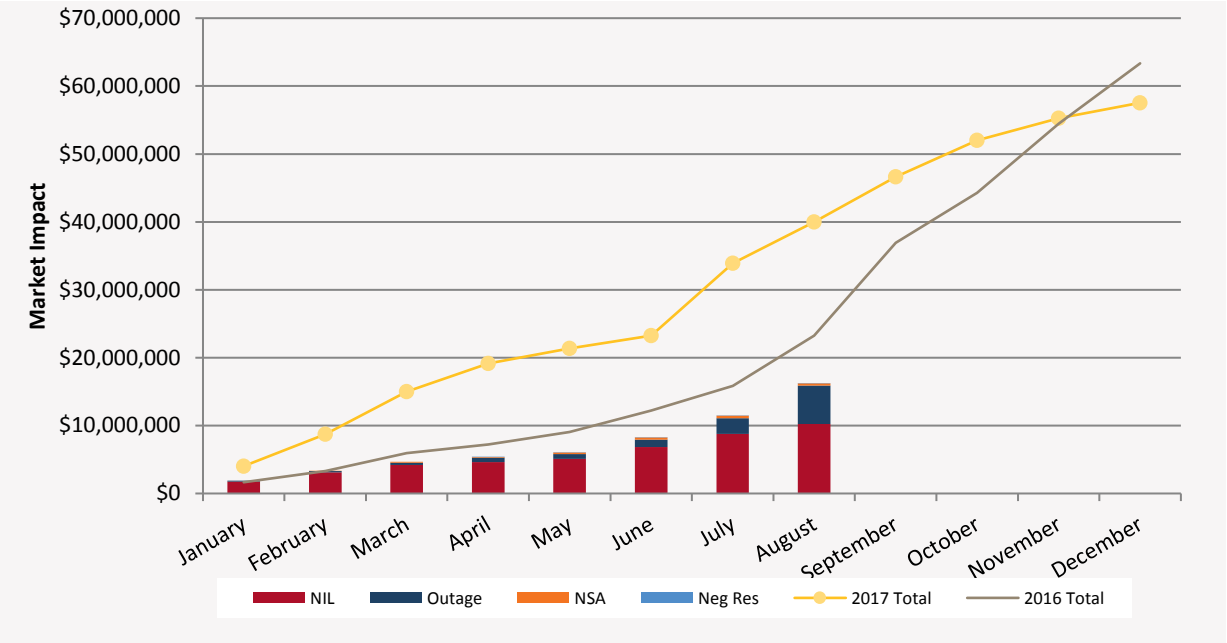
Figure 3 Binding by limit type



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	106	14,137% (93.38)	172% (15.48)
V::N_NIL_V1	Out = NIL, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	21	6,929% (410.22)	505% (172.12)
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.	89	6,747% (244.26)	139.97% (82.88)
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.	19	4,227% (276.07)	441% (93.67)
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.	78	1,716% (84.16)	52.23% (22.09)
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.	42	1,649% (402.59)	107.1% (95.09)

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).	85	1,379% (86.68)	94.48% (24.15)
V::N_BURC_V2	Out = Buronga to Redcliffs (0X1) 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	9	1,246% (353.24)	423% (224.79)
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.	477	894% (9,236)	27.31% (516)
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.	17	793% (181.35)	131.22% (63.35)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

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

V::N_NIL_V1: 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.

S::V_TBSE_TBSE_2: 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_SETB_V2: 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.

V::N_WBHO_V2: 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
Crookwell 2 Wind Farm	1 August 2018	NSW	New Generator
Mt Emerald Wind Farm	14 August 2018	QLD	New Generator
White Rock Solar Farm	21 August 2018	NSW	New Generator
Crush Creek to Strathmore 275 kV transmission line	14 August 2018	QLD	Transmission line commissioned
Mount Emerald to Walkamin Wind Farm 275 kV transmission line	16 August 2018	QLD	Transmission line commissioned
Ross to Lake Ross 132 kV transmission line and Lake Ross No.1 132/33 kV transformer	29 August 2018	QLD	Transmission line and transformer commissioned

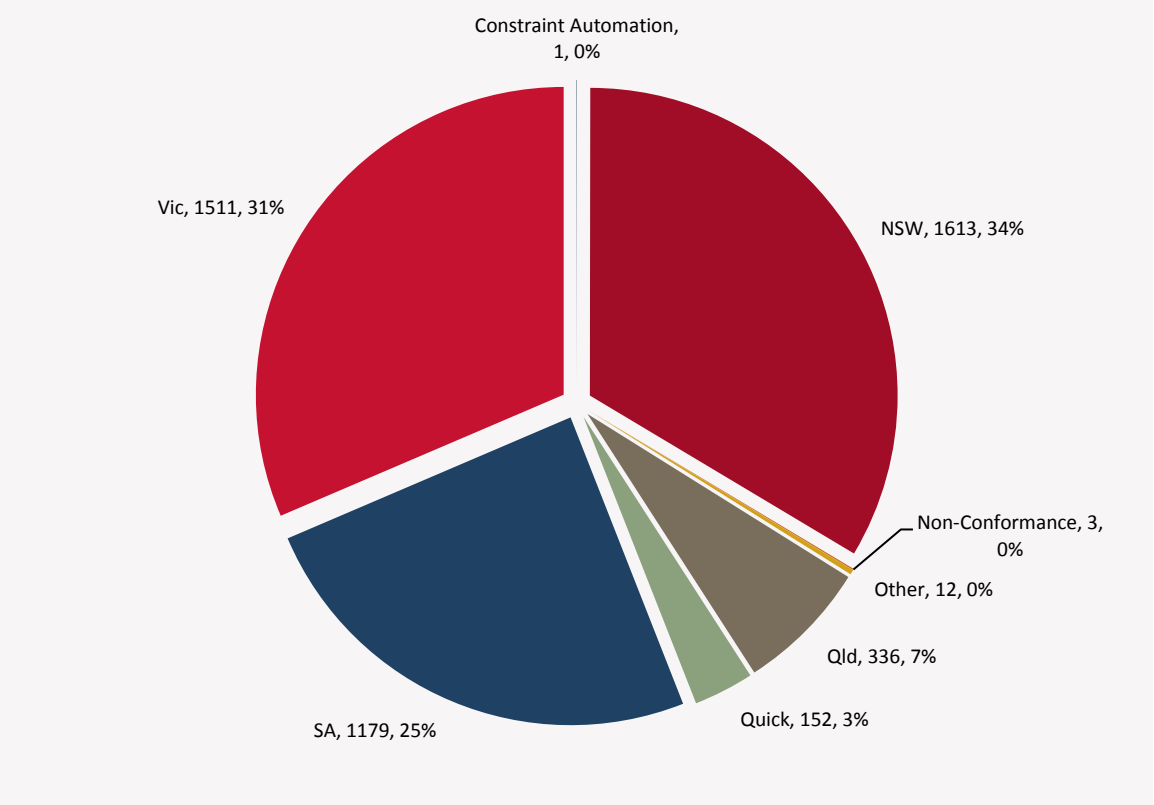
3.1 Constraint Equation Changes

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