AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

September 2019

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 2019. 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
Q^^NIL_QNI_SRAR	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	2612 (217.66)	18/06/2019
N_MBTE1_B	Out= one Directlink cable, Qld to NSW limit	2224 (185.33)	25/11/2013
Q_CS_1850	Qld Central to Qld South upper transfer limit of 1850MW (discretionary)	1901 (158.41)	29/05/2019
S>>PARB_RBTU_WEWT	Out=Para-Robertstown 275kV line, avoid O/L Waterloo East-Waterloo 132kV on trip of Robertstown-Tungkillo 275kV line, Feedback	1455 (121.25)	14/06/2019
Q::N_NIL_AR_2L-G	Out=Nil, limit Qld to NSW on QNI to avoid transient instability for a 2L-G fault at Armidale	946 (78.83)	15/01/2018
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	900 (75.0)	25/11/2013
Q_LILYSF1_ZERO	Lilyvale Solar Farm upper limit of 0 MW	810 (67.5)	20/08/2018
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	791 (65.91)	13/08/2019
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	773 (64.41)	25/01/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
S_NIL_STRENGTH_1	Upper limit (1300 to 1750 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	711 (59.25)	16/09/2019

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
Q_CS_1850	Qld Central to Qld South upper transfer limit of 1850MW (discretionary)	855,397	29/05/2019
S_NIL_STRENGTH_1	Upper limit (1300 to 1750 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	743,427	16/09/2019
Q_LILYSF1_ZERO	Lilyvale Solar Farm upper limit of 0 MW	658,527	20/08/2018
N_STWF1_ZERO	Silverton wind farm upper limit of 0 MW	400,714	6/02/2018
N_BROKENHSF_FLT_26	Limit Broken Hill Solar Farm upper limit to 26 MW to manage post contingent voltage oscillation	383,113	5/09/2019
S>>PARB_RBTU_WEWT	Out=Para-Robertstown 275kV line, avoid O/L Waterloo East-Waterloo 132kV on trip of Robertstown-Tungkillo 275kV line, Feedback	376,750	14/06/2019
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	362,866	23/05/2019
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	351,496	25/01/2019
Q>NIL_COLNVSF1	Out = Nil, Limit Collinsville Solar Farm to thermal rating of Powerlink's RMU	277,699	20/08/2019
S>NIL_TINO3_TINO4	Out = Nil, avoid O/L of TIPS-New Osborne #4 66kV line on trip of TIPS-New Osborne #3 66kV line (Note: Assumed CB 5536 at New Osborne is CLOSED). This constraint swamps out if New Osborne CB 5536 is OPEN.	272,854	14/06/2019

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

Table 1 – Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V^SML_BUDP_3	Out = Buronga to Balranald (X3) or Balranald to Darlington Pt (X5) 220 kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	7 (0.58)	23/09/2019
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	6 (0.5)	29/01/2015
N>N-96H+96R_TE_1	Out= Coffs Harbour to Koolkhan (96H) and Glen Innes to Tenterfield (96R) 132kV line, avoid O/L Armidale to Koolkhan (966) on trip of Coffs Harbour to Lismore (89), Swamp out when all 3 directlink cable O/S,TG formulation for PD/ST	5 (0.41)	21/08/2013
F_T+LREG_0050	Tasmania Lower Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	4 (0.33)	29/01/2015
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	4 (0.33)	14/03/2019
V_SV_MLMO_NETT	Out = Moorabool to Mortlake 500 kV line, TRTS 500kV centre CB fail timer set to zero, No.2 HYTS line CB at APD OPEN, limit nett MW contingency size out of SA to be < 50 MW. Swamp out when MOPS not generating	2 (0.16)	16/09/2019
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
Q>>WOSP_WOPW_WOGP_2	Out= Woolooga to South Pine (807) 275kV line, avoid O/L Woolooga to Gympie (748/2) 132kV line on trip of Woolooga to Palmwoods (810) 275kV line, Feedback	1 (0.08)	12/09/2019
V_WEMENSF_19INV	Limit Wemen Solar Farm upper limit to 0 MW if number of inverter available exceed 19. Constraint swamp out otherwise. DS only	1 (0.08)	5/09/2019
Q>>WOSP_WOPW_WOGP_1	Out= Woolooga to South Pine (807) 275kV line, avoid O/L Woolooga to Gympie (747/2) 132kV line on trip of Woolooga to Palmwoods (810) 275kV line, Feedback	1 (0.08)	12/09/2019

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Table 2 – Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
V^SML_BUDP_3	Constraint equation violated for 7 non-consecutive DIs. Max violation of 15.35 MW occurred on 02/09/2019 at 2340hrs. Constraint equation violated due to competing requirements with Murraylink import limit set by S>V_NIL_NIL_RBNW
F_T+RREG_0050	Constraint equation violated for 6 DIs. Max violation degree of 50 MW occurred for 4 of the 6 DIs. Constraint equation violated due to Tasmania raise regulation service availability being less than the requirement.
N>N-96H+96R_TE_1	Constraint equation violated for 5 DIs. Max violation of 119.58 MW occurred on 24/09/2019 at 0750 hrs. Constraint equation violated due to competing requirements with import constraint QNTE_ROC.
F_T+LREG_0050	Constraint equation violated for 4 DIs with a violation degree of 50 MW for all 4 DIs. Constraint equation violated due to Tasmania lower regulation service availability being less than the requirement
S>SE6161_SETX2_SGBL	Constraint equation violated for 4 DIs. Max violation of 42.61 MW occurred on 02/09/2019 at 1645hrs. Constraint equation violated due to Lake Bonney 2 and Lake Bonney 3 windfarms being limited by their ramp down rate
V_SV_MLMO_NETT	Constraint equation violated for 2 DIs on 16/09/2019 at 1615hrs and 1620 hrs with max violation of 12.73 MW at 1615hrs. Constraint equation violated due to competing requirements with export constraint V_MLMO_VS_LB_CAN_50
F_T_NIL_MINP_R6	Constraint equation violated for 2 DIs on 17/09/2019 at 0655hrs and 0700 hrs with max violation of 3.45 MW at 07:00 hrs. Constraint equation violated due to Tasmania raise 6 seconds service availability being less than the Requirement
Q>>WOSP_WOPW_WOGP_2	Constraint equation violated for 1 DI on 25/09/2019 at 0910hrs with a violation degree of 52.72 MW. Constraint equation violated due to competing requirements with import constraint Q^^NIL_QNI_SRAR
V_WEMENSF_19INV	Constraint equation violated for 1 DI at 12/09/2016 at 1035hrs with violation degree of 34.3 MW. Constraint equation violated due to Wemen Solar farm exceeding its target number of turbines online.
Q>>WOSP_WOPW_WOGP_1	Constraint equation violated for 1 DI on 25/09/2019 at 0910hrs with violation degree of 15.63 MW. Constraint equation violated due to the same reason as Q>>WOSP_WOPW_WOGP_2

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)
Q^^NIL_QNI_SRAR	NSW1-QLD1 Import	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	2586 (215.5)	-927.24 (-1111.48)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N_MBTE1_B	N-Q-MNSP1 Import	Out= one Directlink cable, Qld to NSW limit	2217 (184.75)	-131.38 (-179.8)
S>>PARB_RBTU_WEWT	V-S-MNSP1 Export	Out=Para-Robertstown 275kV line, avoid O/L Waterloo East-Waterloo 132kV on trip of Robertstown-Tungkillo 275kV line, Feedback	1162 (96.83)	-67.41 (63.0)
Q::N_NIL_AR_2L-G	NSW1-QLD1 Import	Out=Nil, limit Qld to NSW on QNI to avoid transient instability for a 2L-G fault at Armidale	926 (77.17)	-1059.97 (-1113.36)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	894 (74.5)	-71.93 (-107.6)
F_S++HYSE_L60	V-SA Import	Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 60 sec Requirement for risk of islanding	797 (66.42)	-86.79 (-168.05)
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	788 (65.67)	-474.09 (-1039.69)
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	773 (64.42)	-136.05 (-194.26)
F_S++HYSE_L6_1	V-SA Import	Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 6 sec Requirement for risk of islanding, segment1	537 (44.75)	-99.21 (-172.51)
S:V_500_HY_TEST	V-SA Import	SA to VIC on Heywood upper transfer limit of 500 MW, limit for testing of Heywood interconnection upgrade.	332 (27.67)	-500.0 (-500.0)

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.

Non-real time constraint automation was not used.

2.5.1 Further Investigation

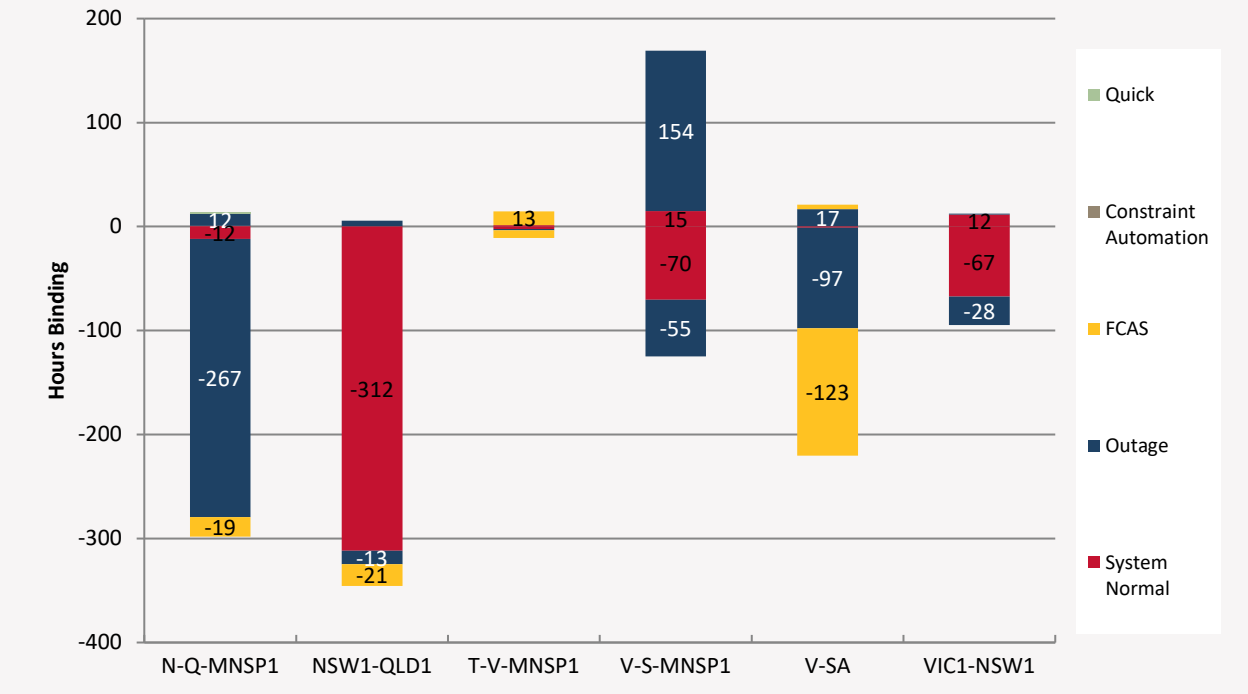
Non-real time constraint automation was not used.

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.

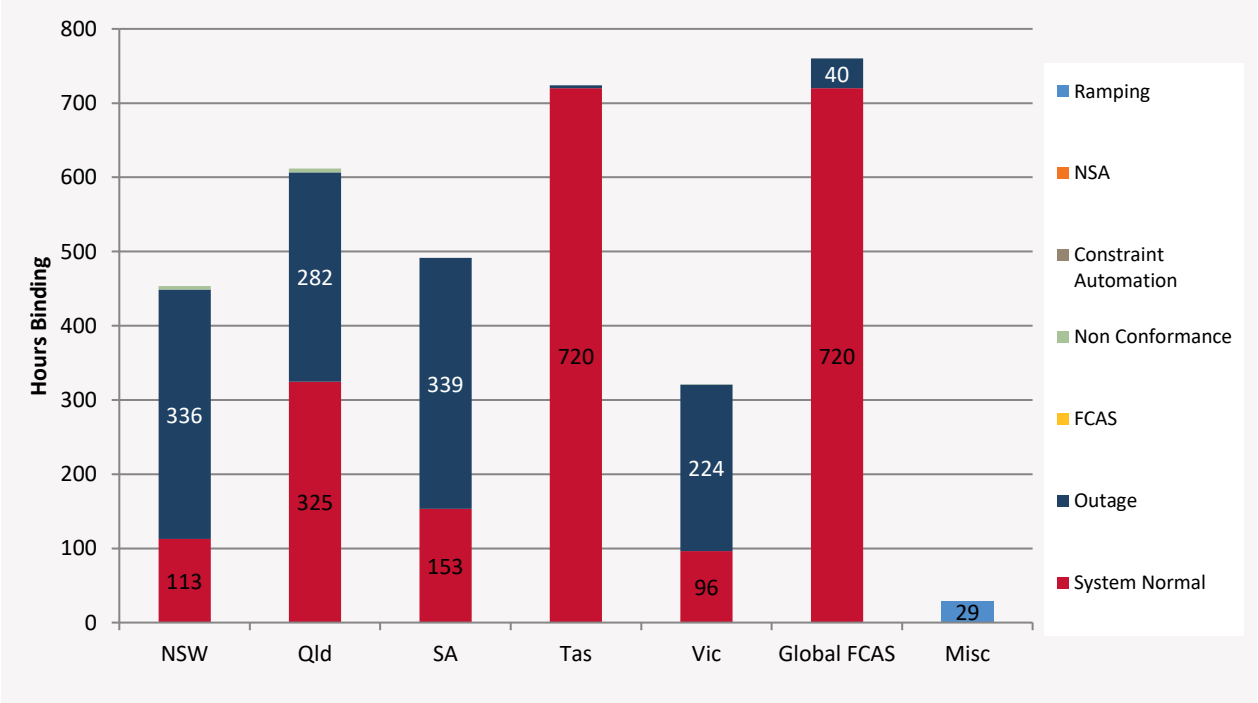
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

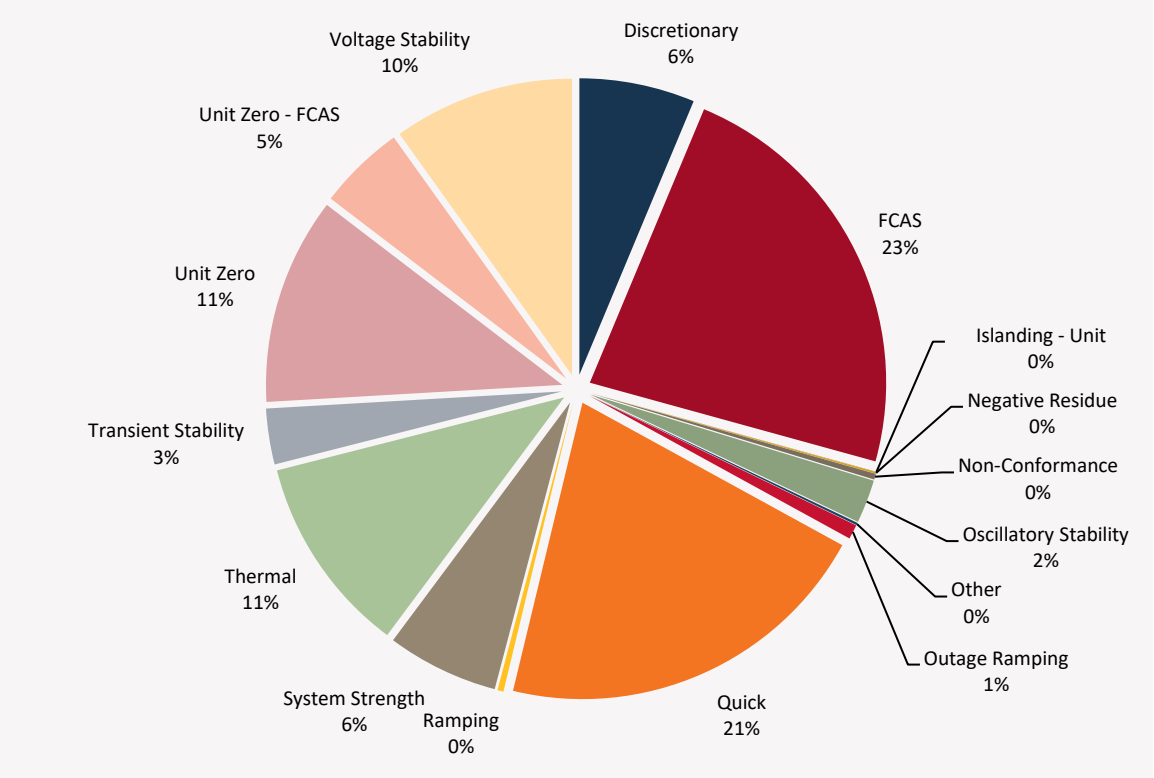
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for September 2019 that the different types of constraint equations bound.

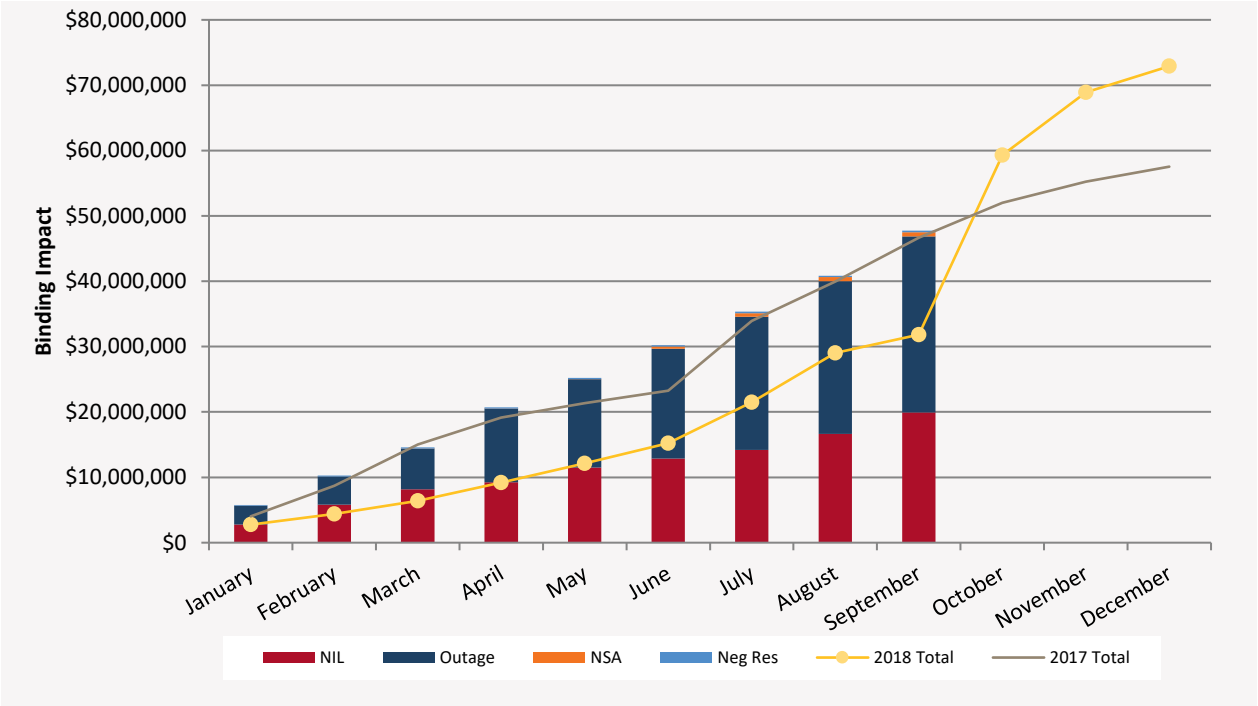
Figure 3 Binding by limit type



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^SML_BUDP_3	Out = Buronga to Balranald (X3) or Balranald to Darlington Pt (X5) 220 kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	44	14,417% (105.98)	665% (41.53)
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	3	7,644% (76.77)	2,987% (65.93)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	4	627% (341.32)	270% (170.54)
V_VS_LB_CAN_50	Limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement when SA is at risk of separation.	38	501% (122.02)	133.37% (44.91)
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to not exceed 45 MW with Broken Hill solar generating	10	444% (200.)	372% (200.)
V^SML_BAWB_3	Out = Ballarat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	3	343% (40.88)	142.63% (26.06)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N^^V_BUDP_1	Out = Buronga to Balranald (X3) or Balranald to Darlington Pt (X5) 220 kV line, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	61	323% (158.1)	86.85% (72.69)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	180	277% (454.16)	52.83% (164.92)
V^SML_ARWB_3	Out = Ararat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	14	136.77% (87.)	93.64% (58.23)
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	28	98.51% (64.92)	40.45% (33.69)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^SML_BUDP_3: Investigated and no improvement can be made to the constraint equation at this stage.

V_T_NIL_FCSPS: This constraint equation uses analog values for the load enabled for the FCSPS in Pre-dispatch. This value can change quickly in dispatch and this is not possible to predict in Pre-dispatch. No changes proposed.

V_VS_LB_CAN_50: Investigated and no improvement can be made to the constraint equation at this stage.

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

N^^V_BUDP_1: Investigated and no improvement 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.

S>SE6161_SETX2_SGBL: 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 for September 2019.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Oakey 2 Solar Farm	3 September 2019	QLD1	New Generator.
Commissioning of two new 220 kV CBs at Balranald Substation	4 September 2019	NSW	New CBs installed at Balranald. Previous X5/1 (Balranald to Darlington Point) and X5/3 (Buronga to Balranald) T lines to become X5 and X3 220 kV transmission lines respectively.
Commissioning of Waddamana - Wild Cattle Hill 220 kV line	25 September 2019	TAS	New transmission line.

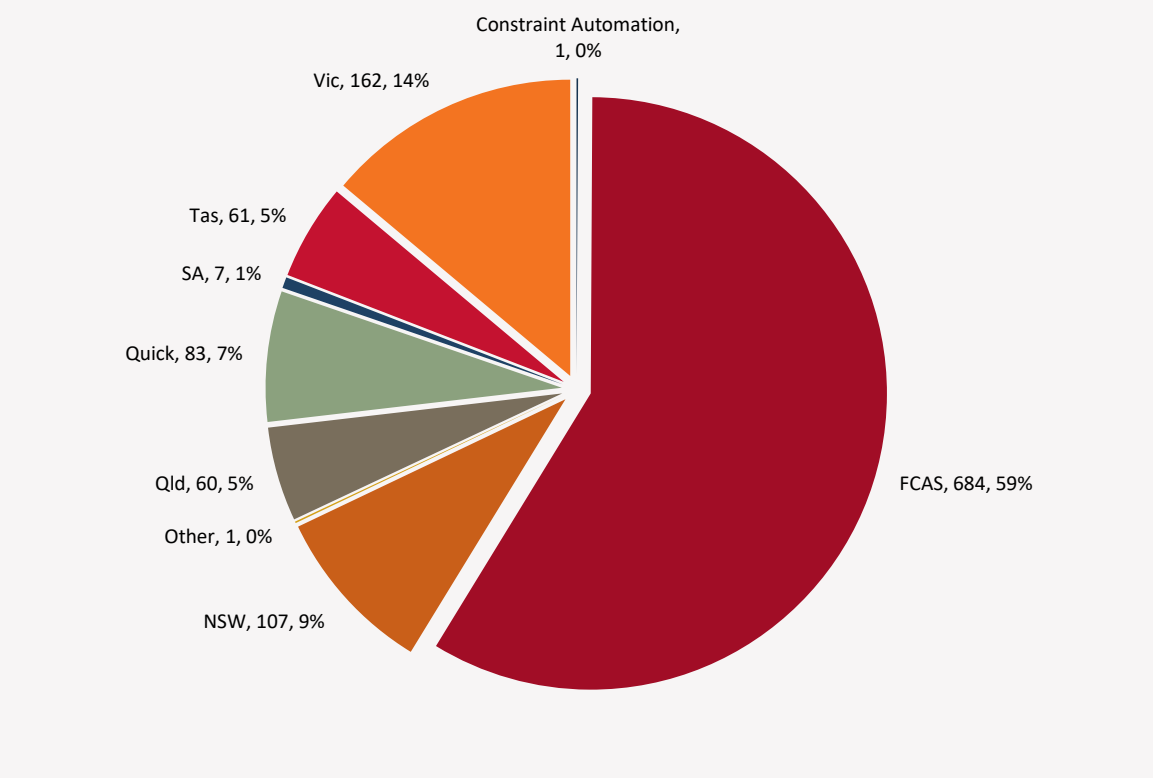
3.1 Constraint Equation Changes

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