Monthly Constraint Report

August 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 August 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
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	3079 (256.58)	13/08/2019
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	2701 (225.08)	18/06/2019
N_MBTE1_B	Out= one Directlink cable, Qld to NSW limit	1295 (107.91)	25/11/2013
Q>NIL_BI_CAGS_CALV_C	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV intact between T022 Callide A and H015 Lilyvale.	851 (70.91)	11/01/2019
S>>PARB_RBTU_WEWT	Out=Para-Robertstown 275kV line, avoid O/L Waterloo East-Waterloo 132kV on trip of Robertstown-Tungkillo 275kV line, Feedback	795 (66.25)	14/06/2019
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	794 (66.16)	25/01/2019
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 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.	788 (65.66)	23/07/2019
V_BANSF_BBD_60	Out = Nil, Limit Bannerton SF upper limit to 60 MW if Boundary Bend (BBD) loading is less than 10 MW, DS only. Swamp out if BBD loading is 10 MW or above.	730 (60.83)	16/08/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
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	706 (58.83)	7/08/2019
V_KIATAWF_FLT_0	Limit Kiata Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	654 (54.5)	19/07/2019

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
V_BANSF_BBD_60	Out = Nil, Limit Bannerton SF upper limit to 60 MW if Boundary Bend (BBD) loading is less than 10 MW, DS only. Swamp out if BBD loading is 10 MW or above.	777,868	16/08/2019
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 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.	755,315	23/07/2019
V>V_ELTS_TX_R2	Out = Elaine R2 220/132kV transformer, limit Mt Mercer WF MW output to avoid overloading the remaining in service R1 220/132kV transformer.	611,544	16/05/2018
V_MURRAWRWF_FLT_25	Limit Murra Warra Wind Farm upper limit to 25 MW to manage system stability on the next contingency due to voltage oscillation	287,818	19/07/2019
V_MURRAWRWF_FLT_50	Limit Murra Warra Wind Farm upper limit to 50 MW to manage system stability on the next contingency due to voltage oscillation	270,146	29/08/2019
N_BROKENHSF_FLT_30	Limit Broken Hill Solar Farm upper limit to 30 MW to manage post contingent voltage oscillation	258,830	19/07/2019
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	252,111	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	225,588	25/01/2019

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.

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Change Date
S>>PARB_RBTU_WEWT	Out=Para-Robertstown 275kV line, avoid O/L Waterloo East-Waterloo 132kV on trip of Robertstown-Tungkillo 275kV line, Feedback	203,077	14/06/2019
V_CWWF_FLT_50	Limit Crowlands Wind Farm upper limit to 50 MW to manage system stability on the next contingency	181,941	29/08/2019

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
S^SETX_GEN_CAP	Out= One South East 275/132kV transformer O/S, avoid local voltage collapse on trip of remaining South East transformer,	9 (0.75)	28/05/2019
Q>NIL_BI_CAGS_CALV_C	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV intact between T022 Callide A and H015 Lilyvale.	7 (0.58)	11/01/2019
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	6 (0.5)	6/05/2015
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	5 (0.41)	27/08/2018
N>N-LSTN_TE_C1	Out= Lismore to Tenterfield (96L), avoid O/L Koolkhan to Lismore (967), on trip of Coffs Harbour to Lismore (89), Swamp out when all 3 directlink cable O/S, Feedback, TG formulation in PD/ST	5 (0.41)	21/08/2013
NSA_V_BDL02_20	Bairnsdale Unit 2 >= 20 MW for Network Support Agreement	3 (0.25)	21/08/2013
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	3 (0.25)	2/12/2016
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	2 (0.16)	29/01/2015
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	2 (0.16)	4/05/2018
S>SETXH1_SETXL2	Constraint Automation, O/L S_EAST TRANSF T_2 for CTG TSHZ on trip of S_EAST 1 275/132KV TX. Generated by RTCA[EMS]	1 (0.08)	27/08/2019

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
S^SETX_GEN_CAP	Constraint equation violated for 9 non-consecutive DIs. Max violation of 20.59 MW occurred on 16/08/2019 at 0935hrs. Constraint violated due to Lake Bonney 2 wind farm being limited by its ramp-down rate.
Q>NIL_BI_CAGS_CALV_C	Constraint equation violated for 7 non-consecutive DIs. Max violation of 10.75 MW occurred on 11/08/2019 at 1720hrs. Constraint equation violated due to Gladstone unit 4 being limited by its ramp-down rate.
NSA_Q_BARCALDN	Constraint equation violated for 6 non-consecutive DIs. Max violation of 8.67 MW occurred on 10/08/2019 at 0920hrs. Constraint equation violated due to Barcaldine unit being limited by its start-up profile.
N^N-LS_SVC	Constraint equation violated for 5 DIs. Max violation of 10.39 MW occurred on 28/08/2019 at 1815 hours. Constraint equation violated due to competing requirements with import constraint N_X_MBTE2_B.
N>N-LSTN_TE_C1	Constraint equation violated for 5 DIs. Max violation of 7.25 MW occurred on 29/08/2019 at 1805 hrs. Constraint violated due to competing requirements with import constraint Q>NIL_MUTE_757.
NSA_V_BDL02_20	Constraint equation violated for 3 DIs. Max violation of 20 MW occurred on 16/08/2019 at 0845hrs and 0850hrs. Constraint violated due to Bairnsdale unit 2 being unavailable.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 3 DIs. Max violation of 7.33 MW occurred on 25/08/2019 at 1815hrs. Constraint violated due to Tasmania raise 6 seconds service availability being less than the Requirement.
F_T+RREG_0050	Constraint equation violated for 2 DI on 24/08/2019 at 1430hrs with a violation degree of 50 MW. Constraint equation violated due to Tasmania raise regulation service availability being less than the requirement.
F_T_AUFLS2_R6	Constraint equation violated for 2 DIs. Max violation of 18.19 MW occurred on 21/08/2019 at 0540hrs. Constraint equation violated due to the same reason as F_T+NIL_MG_RECL_R6
S>SETXH1_SETXL2	This is a real-time Constraint Automation constraint equation. Constraint equation violated for 1 DI on 07/08/2019 at 1650hrs with a violation degree of 742.4 MW. The constraint equation violated due to a formulation issue. The constraint equation has now been removed from real-time Constraint Automation and is currently under investigation. There was no power system security issue during the period when the constraint equation violated.

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)
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	3079 (256.58)	-252.74 (-1020.74)

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	2698 (224.83)	-939.48 (-1077.3)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1457 (121.42)	273.01 (478.0)
N_MBTE1_B	N-Q-MNSP1 Import	Out= one Directlink cable, Qld to NSW limit	1295 (107.92)	-134.51 (-186.7)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	793 (66.08)	292.46 (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	789 (65.75)	-170.33 (-200.9)
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	724 (60.33)	-100.23 (29.62)
V_SV_MLMO_NETT	V-SA Import	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	693 (57.75)	67.88 (-50.0)
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	527 (43.92)	61.05 (-463.1)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	512 (42.67)	-76.6 (-128.1)

2.5 Constraint Automation Usage

The constraint automation is an application in AEMO's energy management system (EMS) which generates thermal overload constraint equations based on the current or planned state of the power system. It is currently used by on-line staff to create thermal overload constraint equations for power system conditions where there were no existing constraint equations or the existing constraint equations did not operate correctly.

The following section details the reason for each invocation of the non-real time constraint automation constraint sets and the results of AEMO's investigation into each case.

Table 3 – Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_MQS_4C6B1A92	18/08/2019 09:35 to 18/08/2019 11:30	Automated constraint equation was created to manage thermal overload on North West Bend 66/132kV transformer No.1 for loss of North West Bend to Monash 132kV line during prior outage of North West Bend 132kV circuit breaker No.6225. Existing constraint equation S>NWBCB6225_TX1 has been updated

2.5.1 Further Investigation

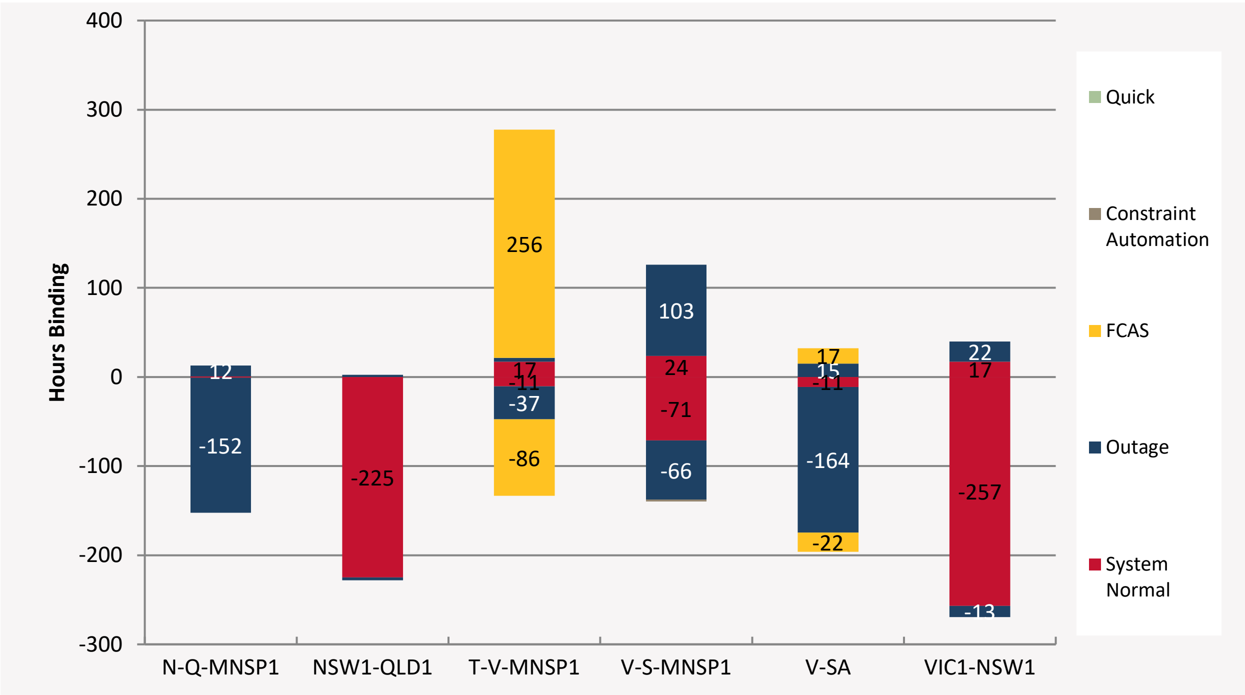
CA_MQS_4C6B1A92: Investigated and constraint equation S>NWBCB6225_TX1 has been updated. No further action required

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.

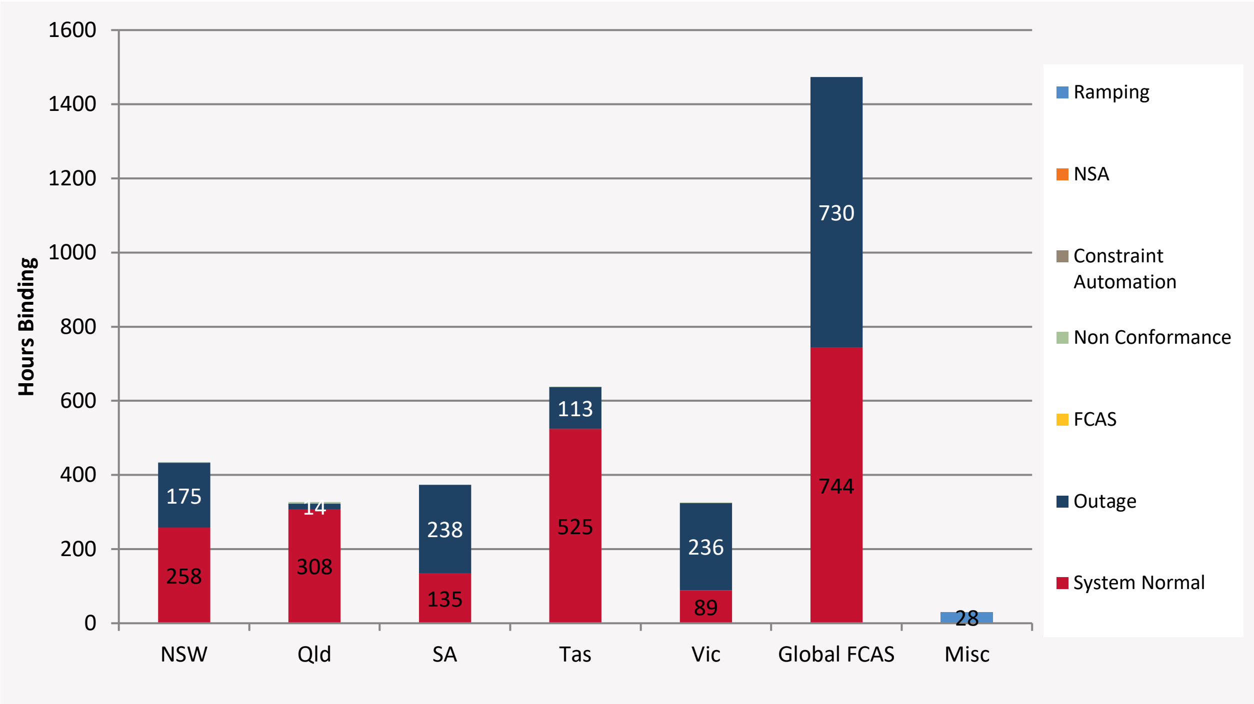
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

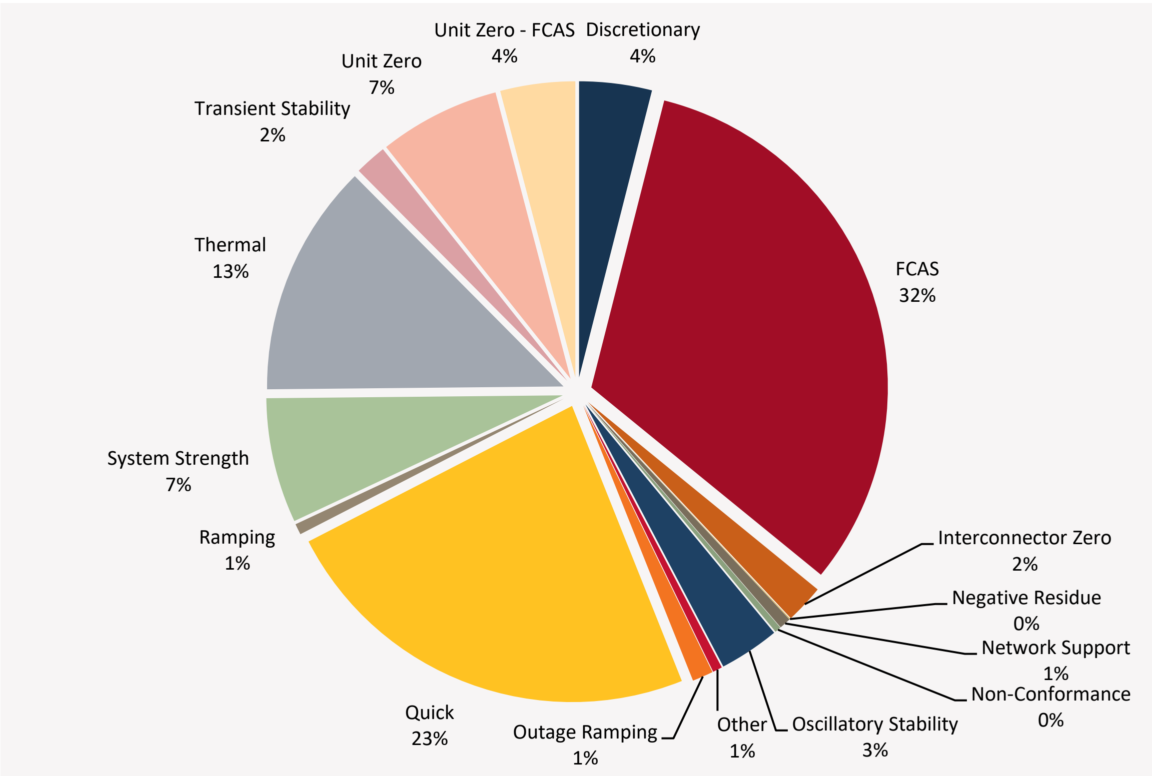
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

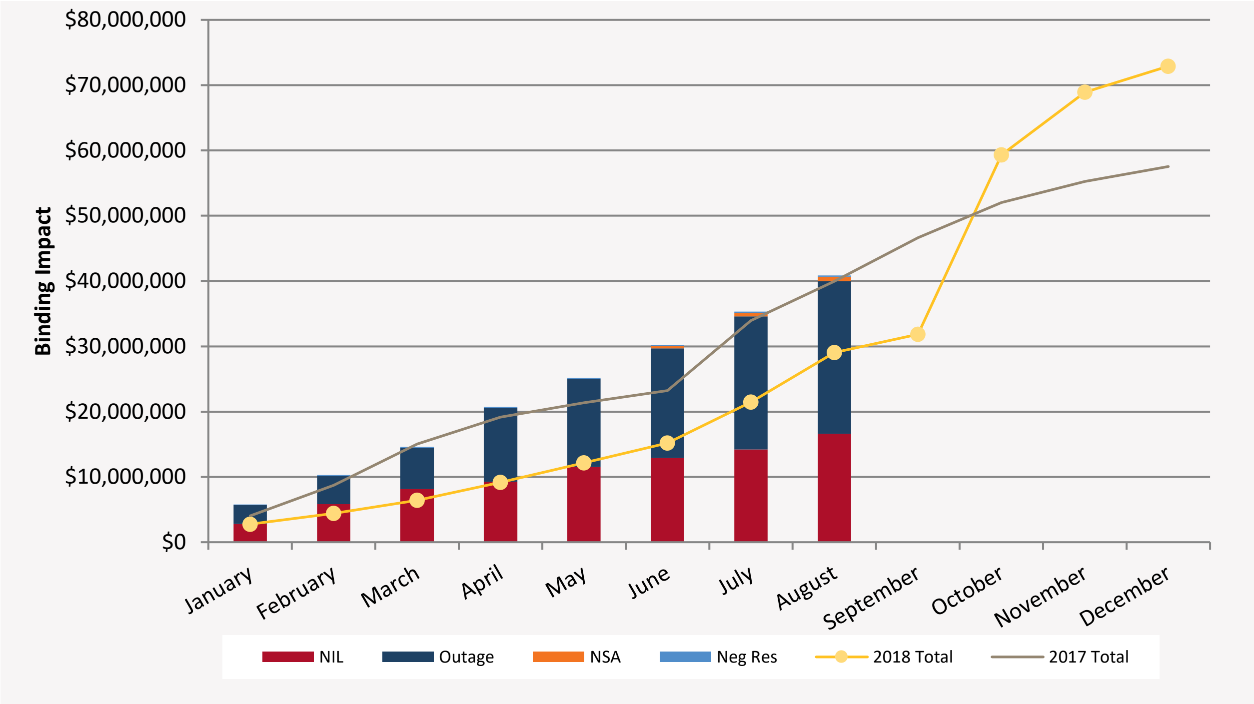
Figure 3 Binding by limit type



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
N^^V_BUDP_1	Out = Buronga to Balranald to Darlington Pt (X5) 220 kV line, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	7	6,617% (282.22)	2,424% (199.92)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	631	5,848% (528)	122.74% (135.33)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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	14	4,021% (83.96)	619% (40.35)
V::N_DDSM_V2	Out = Dederang to South Morang 330kV line, prevent transient instability for fault and trip of the parallel Dederang to South Morang 330kV line, VIC accelerates, Yallourn W G1 on 500 kV.	18	2,962% (236.74)	480% (110.79)
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	23	1,061% (74.94)	149.02% (39.35)
N^^V_DDSM1	Out = Dederang to South Morang 330 kV line, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink or the parallel Dederang to South Morang 330kV line	17	455% (87.52)	70.73% (46.23)
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to not exceed 45 MW with Broken Hill solar generating	5	444% (200.)	444% (200.)
V::N_SMSC_V2	Out = one South Morang series capacitor, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	18	361% (147.06)	94.82% (84.09)
V::N_SMSC_S2	Out = one South Morang series capacitor, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	8	154% (80.26)	63.13% (48.08)
V^SML_BUDP_3	Out = Buronga to Balranald to Darlington Pt (X5) 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	3	108.43% (32.92)	62.78% (18.42)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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.

V::N_DDSM_V2: Investigated and no improvement can be made to the constraint equation at this stage.

N^^V_DDSM1: 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.

V::N_SMSC_V2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_SMSC_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 for August 2019.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
N/A			

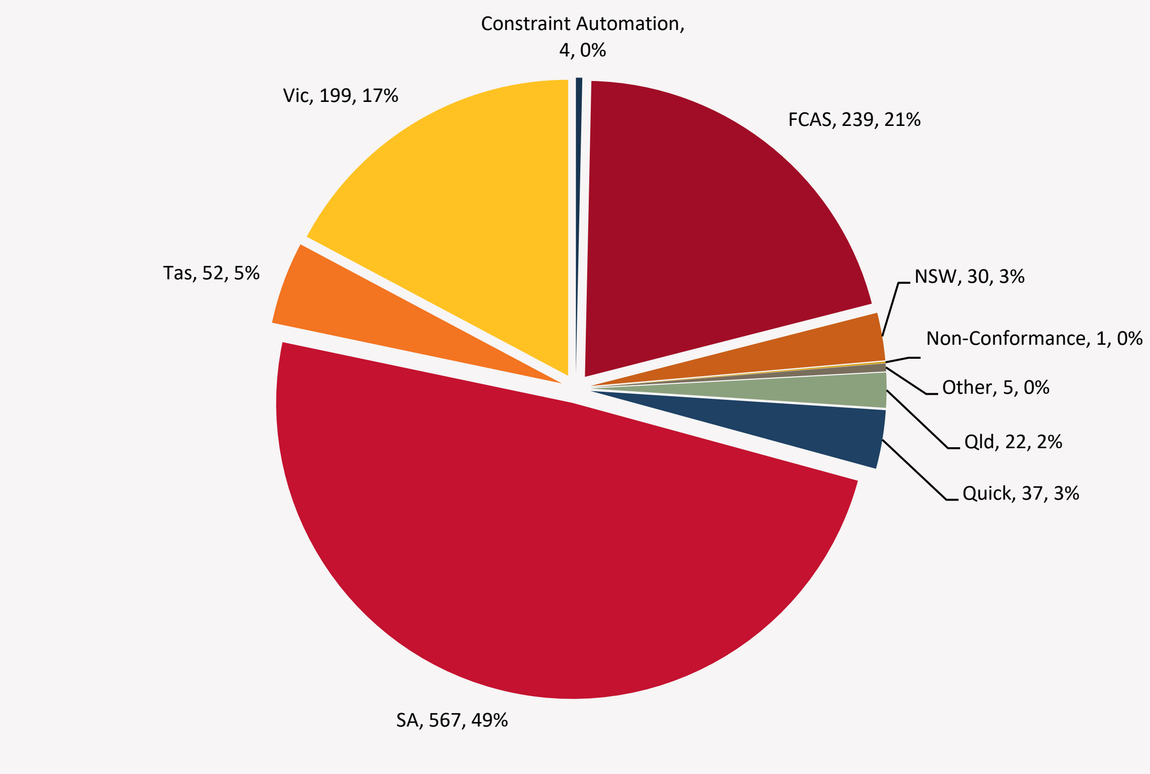
3.1 Constraint Equation Changes

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