Monthly Constraint Report

September 2021

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 2021. 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)	Limit Type
T::T_NIL_1	Out = NIL, prevent transient instability for fault and trip of a Farrell to Sheffield line, Swamp if less than 3 synchronous West Coast units generating or Farrell 220kV bus coupler open or Hampshire 110kV line is closed.	3193 (266.08)	Transient Stability
T_MRWF_FOS	Limit Musselroe wind farm due to upper limit on Tasmanian generator events. Limit is 153 MW (effective 144 MW at the connection point at Derby)	2592 (216.0)	Other
S>NIL_MHNW1_MHNW2	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	1944 (162.0)	Thermal
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1819 (151.58)	Thermal
N^^N_NIL_2	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	1819 (151.58)	Voltage Stability
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria	1418 (118.16)	Voltage Stability
Q>>CPST_CLWU_RGLC	Out= 812+848 (H67 Calliope River to H10 Bouldercombe to H29 Stanwell) 275 kV feeders, avoid O/L Raglan to Larcom Creek (8875) on trip of Calvale to Wurdong (871) line, Feedback	1199 (99.91)	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	1133 (94.41)	Thermal

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
S-X_2DV+2RB_STRGHT_1	Out = 2 x Davenport + 2 x Robertstown synchronous condensers O/S, Upper limit (1300 to 1750 MW) for SA ASG for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	1052 (87.66)	System Strength
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	944 (78.66)	Voltage Stability

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	Limit Type
N^^N_NIL_2	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	2,186,059	Voltage Stability
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1,945,881	Thermal
S-X_2DV+2RB_STRGHT_1	Out = 2 x Davenport + 2 x Robertstown synchronous condensers O/S, Upper limit (1300 to 1750 MW) for SA ASG for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	959,803	System Strength
S>NIL_MHNW1_MHNW2	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	926,413	Thermal
Q>>CPST_CLWU_RGLC	Out= 812+848 (H67 Calliope River to H10 Bouldercombe to H29 Stanwell) 275 kV feeders, avoid O/L Raglan to Larcom Creek (8875) on trip of Calvale to Wurdong (871) line, Feedback	826,804	Thermal
T_MRWF_FOS	Limit Musselroe wind farm due to upper limit on Tasmanian generator events. Limit is 153 MW (effective 144 MW at the connection point at Derby)	737,736	Other
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria	580,927	Voltage Stability
V_CWWF_FLT_0	Limit Crowlands Wind Farm upper limit to 0 MW to manage post contingent voltage oscillation	504,564	System Strength

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	Limit Type
V_ARARATWF_FLT_0	Limit Ararat Wind Farm upper limit to 0 MW to manage post contingent voltage oscillation	501,437	System Strength
N>>N-NIL_94B_9ML	Out= Nil, avoid O/L Bodangora to Wellington (94B/1) on trip of Crudine Ridge to Ilford Tee (9ML) line, Feedback. Metering is used as specified in OM520	476,281	Thermal

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)	Limit Type
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	40 (3.33)	Negative Residue
N_BROKENH1_0INV	Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	11 (0.91)	System Strength
N_LIMOSF1_0INV	Constraint to violate if Limondale 1 Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	11 (0.91)	System Strength
Q_STR_8C7C1S_SMSF	No limit Sun Metals SF output if Stan>=2+Cal>=2+Glad>=2+ (Stan+Cal+Glad) >=8,NQLD>450&470(AVG),Ross_FN>250&270(AVG)(Kar>=2 if NQLD>350&370(AVG),Ross_FN>150&170(AVG),80% if Stan>=1+(Stan+Cal+Glad) >=7+Kar>=2. Zero otherwise.	8 (0.66)	System Strength
N_DARLSF_FLT_110	Limit Darlington Pt Solar Farm upper limit to 110 MW to manage post contingent voltage oscillation	7 (0.58)	System Strength
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	7 (0.58)	Network Support
Q_NIL_STRGTH_SMSF	Out = Nil, limit Sun Metal SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	6 (0.5)	System Strength
Q_STR_8C7C1S_RRSF	No limit Ross River SF if Stan>=2+Cal>=2+Glad>=2+(Stan+Cal+Glad)>=8+Kar>=2,NQLD>350&370(AVG),Ross_FN>250&,470(AVG),(NQLD>450&470(AVG),Ross_FN>250&270(AVG), Stan>=3+Kar=0),50% if Stan>=2+Kar=0) ,80% if Stan>=1+(Stan+Cal+Glad) >=7+Kar>=2. 0 otherwise	5 (0.41)	System Strength
N>N-ARKK_CH_CB892A	Out= Armidale to Koolkhan (966) and Coffs Harbour CB 892 opened, avoid O/L Armidale to Coffs Harbour (96C)132kV line, on trip of Armidale to Coffs Harbour (87) 330kV line, Swamp out when all 3 directlink cable O/S, Feedback. TG formulation in PD/ST	4 (0.33)	Thermal
N_FINLYSF1_0INV	Constraint to violate if Finley solar farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	2 (0.16)	System Strength

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
NRM_QLD1_NSW1	Constraint equation violated for 40 non-consecutive DIs with max violation of 204.34 MW occurring on 20/09/2021 at 1740 hrs. Constraint equation violation occurred due to competing requirements with the export limits which were set by N^^Q_TW_330_BUS3_B1, N>N-NIL_LSDU, N_MBTE1_A, Q>>CPST_CLWU_RGLC, and Q>>CPST_CLWU_BCST.
N_BROKENH1_0INV	Constraint equation violated for 11 non-consecutive DIs with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit.
N_LIMOSF1_0INV	Constraint equation violated for 11 consecutive DIs on 15/09/2021 from 1905 hrs to 1955 hrs with violation degree of 0.001 MW. Constraint equation violation occurred due to Limondale 1 Solar Farm exceeding its inverter limit.
Q_STR_8C7C1S_SMSF	Constraint equation violated for 8 non-consecutive DIs with violation degree 0.001 MW. Constraint violation occurred due to Sun Metals Solar Farm exceeding its MVar limit.
N_DARLSF_FLT_110	Constraint equation violated for 7 consecutive DIs on 21/09/2021 from 0745 hrs to 0815 hrs with max violation of 116.36 MW occurring at 0815 hrs. Constraint equation violation occurred due to Darlington Point Solar Farm non-conforming.
NSA_V_NPSD_100	Constraint equation violated for 7 non-consecutive DIs on 25/09/2021 and 26/09/2021 with max violation of 67.75 MW occurring on 25/09/2021 at 1105 hrs. Constraint equation violation occurred due to Newport unit being limited by its start-up profile.
Q_NIL_STRGTH_SMSF	Constraint equation violated for 6 consecutive DIs on 22/09/2021 from 1050 hrs to 1115 hrs with violation degree 0.001 MW. Constraint equation violation occurred due to Sun Metal Solar Farm exceeding its MVar limit.
Q_STR_8C7C1S_RRSF	Constraint equation violated for 5 DIs with violation degree 0.001 MW. Constraint equation violation occurred due to Ross River Solar Farm exceeding its MVar limit.
N>N-ARKK_CH_CB892A	Constraint equation violated for 4 DIs with max violation of 66.07 MW occurring on 14/09/2021 at 1820 hrs. Constraint equation violation occurred due to competing requirements with the import limits on N-Q-MNSP1 which were set by QNTE_ROC.
N_FINLYSF1_0INV	Constraint equation violated for 2 DIs on 17/09/2021 at 0635 hrs and 0640 hrs with violation degree 0.001 MW. Constraint equation violation occurred due to Finley Solar Farm exceeding its inverter limit.

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	1955 (162.92)	403.61 (459.01)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
S>NIL_MHNW1_MHNW2	V-S-MNSP1 Export	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	1883 (156.92)	150.46 (176.67)
F_Q++BCDM_L6	NSW1-QLD1 Import	Out = Bulli Creek to Dumaresq (8L or 8M) or Dumaresq to Sapphire (8J) line, Qld Lower 6 sec Requirement	1249 (104.08)	-132.57 (-289.3)
N^^N_NIL_3	VIC1-NSW1 Export	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria	1248 (104.0)	138.35 (902.09)
Q>>CPST_CLWU_RGLC	NSW1-QLD1 Export	Out= 812+848 (H67 Calliope River to H10 Bouldercombe to H29 Stanwell) 275 kV feeders, avoid O/L Raglan to Larcom Creek (8875) on trip of Calvale to Wurdong (871) line, Feedback	1125 (93.75)	-451.31 (30.47)
N^^N_NIL_2	V-S-MNSP1 Import	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	1004 (83.67)	134.78 (-141.08)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	941 (78.42)	807.21 (987.67)
N_MBTE1_B	N-Q-MNSP1 Import	Out= one Directlink cable, Qld to NSW limit	927 (77.25)	-116.43 (-154.7)
Q>>BCST_BCST_CLWU	NSW1-QLD1 Export	Out = 848 or 849 H10 Bouldercombe to H29 Stanwell 275 kV line, avoid O/L the remaining Stanwell to Bouldercombe 848 or 849 on trip of Calvale to Wurdong (871) line, Feedback	810 (67.5)	-238.82 (294.88)
N^^N_NIL_3	V-S-MNSP1 Import	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria	712 (59.33)	130.29 (-139.64)

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

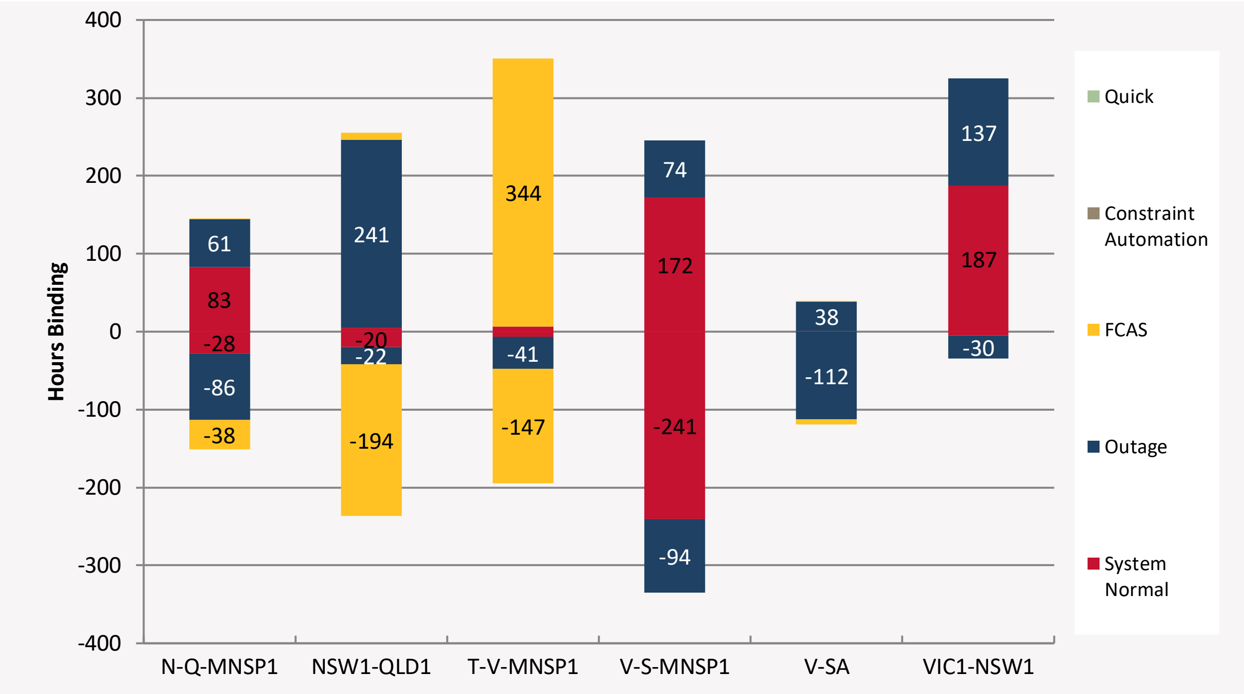
Non-real time constraint automation was not used.

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.

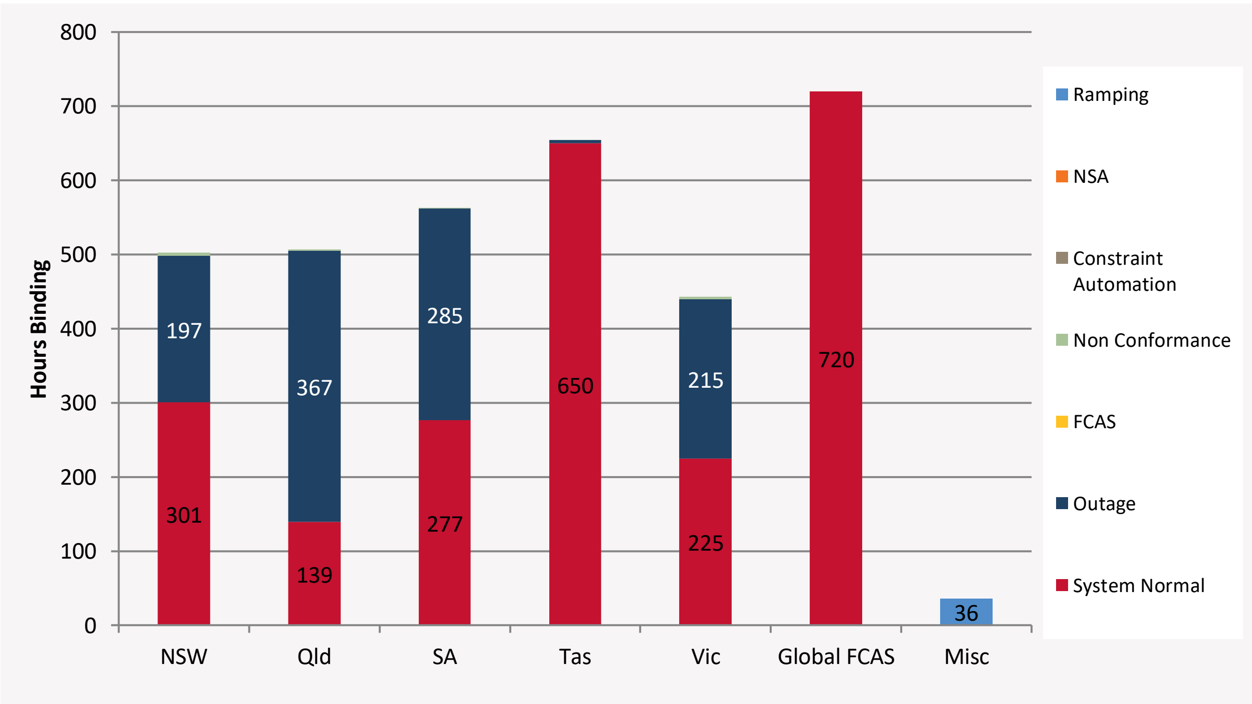
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

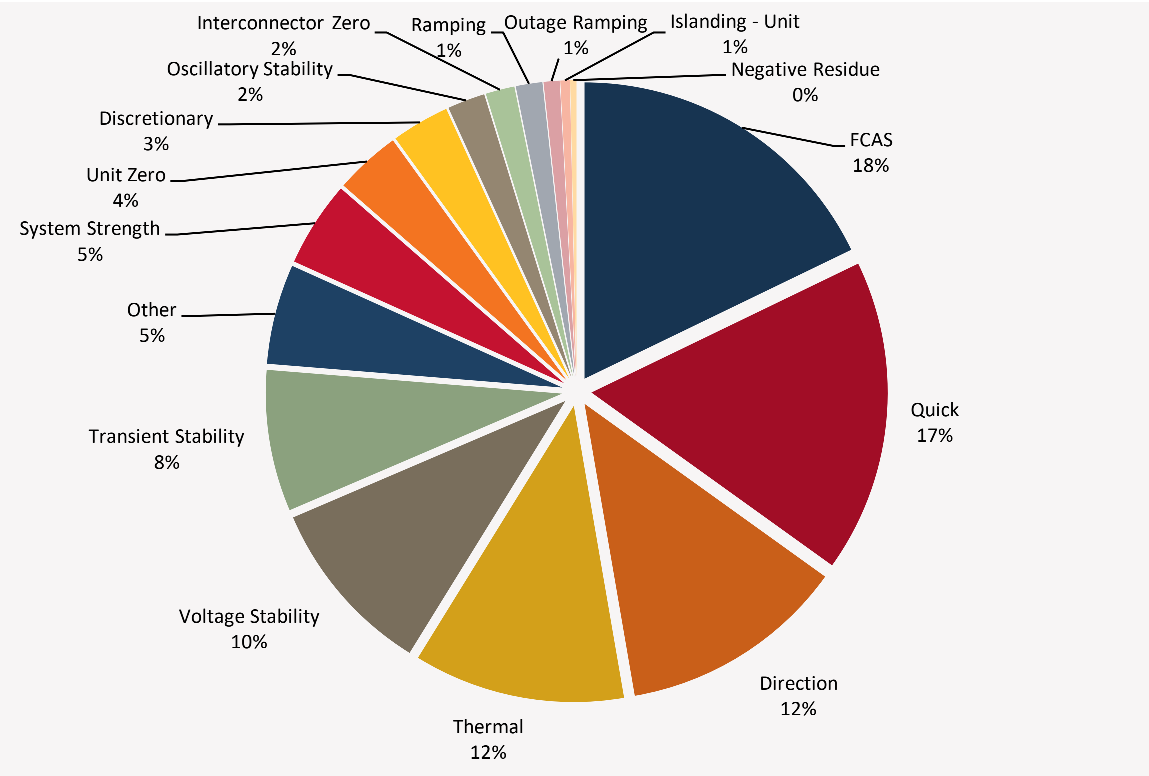
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for September 2021 that the different types of constraint equations bound.

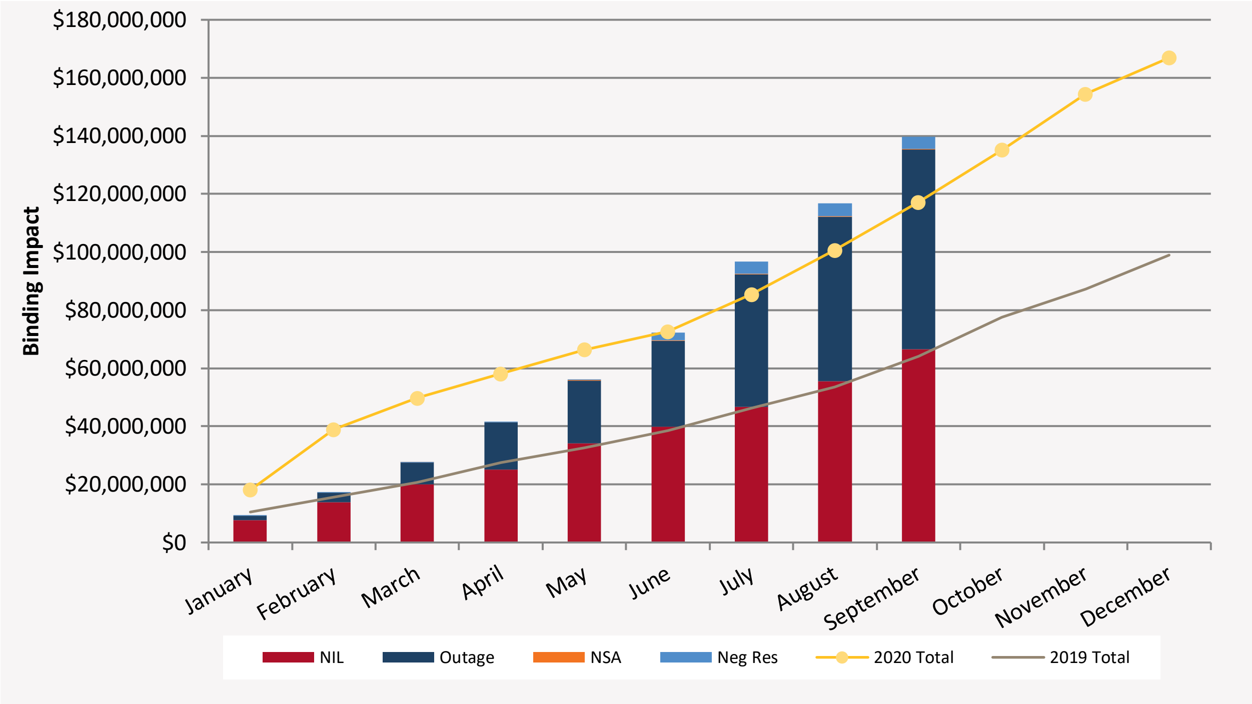
Figure 3 Binding by limit type



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	19	2,259% (121.44)	253% (44.81)
V_S_HEYWOOD_UFLS	Out= Nil, Limit Heywood flows when SA under frequency load shedding (UFLS) is insufficient (i.e. when UFLS blocks in SA <1000 MW) to manage for double-circuit loss of Heywood IC.Note: Constraint is swamped if UFLS blocks >= 1000 MW.	9	1,842% (9,485)	465% (2,237)
V^^SML_ARWBBA_1	Out = Ballarat to Waubra to Ararat 220kV line (or any line section between Ballarat and Ararat), avoid voltage collapse for loss of Bendigo to Kerang 220kV line	6	1,498% (103.53)	374% (60.22)
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.	10	1,284% (225.6)	251% (109.5)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	17	870% (23.7)	112.97% (7.5)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
S-X_2DV+2RB_STRGHT_1	Out = 2 x Davenport + 2 x Robertstown synchronous condensers O/S, Upper limit (1300 to 1750 MW) for SA ASG for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	184	870% (9,426)	16.31% (438.27)
V::N_DDSM_V1	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 220 kV.	87	441% (257.19)	43.31% (83.36)
V::N_HWSM_S1	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, SA accelerates	4	356% (177.52)	118.6% (93.99)
S>NIL_HUWT_STBG2	Out = Nil; Limit Snowtown WF generation to avoid Snowtown - Bungama line OL on loss of Hummocks - Waterloo line.[Note: Wattle PT trips when generating >=80 MW when Dalymple Battery (i.e. both Gen and Load component) is I/S]	55	301% (146.79)	82.62% (57.33)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	30	220% (25.8)	54.47% (8.51)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_HWSM_V1: Investigated and no improvement can be made to the constraint equation at this stage.

N_X_MBTE_3A: Investigated and no improvement can be made to the constraint equation at this stage.

S-X_2DV+2RB_STRGHT_1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_DDSM_V1: Investigated and no improvement can be made to the constraint equation at this stage.

S>NIL_HUWT_STBG2: Investigated and no improvement can be made to the constraint equation at this stage.

N_X_MBTE_3B: 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 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Dumaresq 8L2A 330kV Circuit Breaker	16/09/2021	NSW	At Dumaresq substation the 8L2A 330 kV circuit breaker was commissioned
Smartwires - Vic - NSW	19/09/2021	Victoria	At Wodonga 330 kV substation Smartwires FACTS devices were commissioned on Jindera - Wodonga 060 330 kV line.
Tamworth 330 kV No 5112 Circuit Breaker	22/09/2021	NSW	At Tamworth a new 330 kV bus section circuit breaker CB 5112 was commissioned
Dumaresq No 1 330 kV 125 MVAr Capacitor	29/09/2021	NSW	At Dumaresq substation the No 1 330 kV 125 MVAr capacitor was commissioned
Dumaresq No 2 330 kV 125 MVAr Capacitor	29/09/2021	NSW	At Dumaresq substation the No 2 330 kV 125 MVAr capacitor was commissioned
Torrens Island A Unit 1	30/09/2021	SA	Deregistered Generator

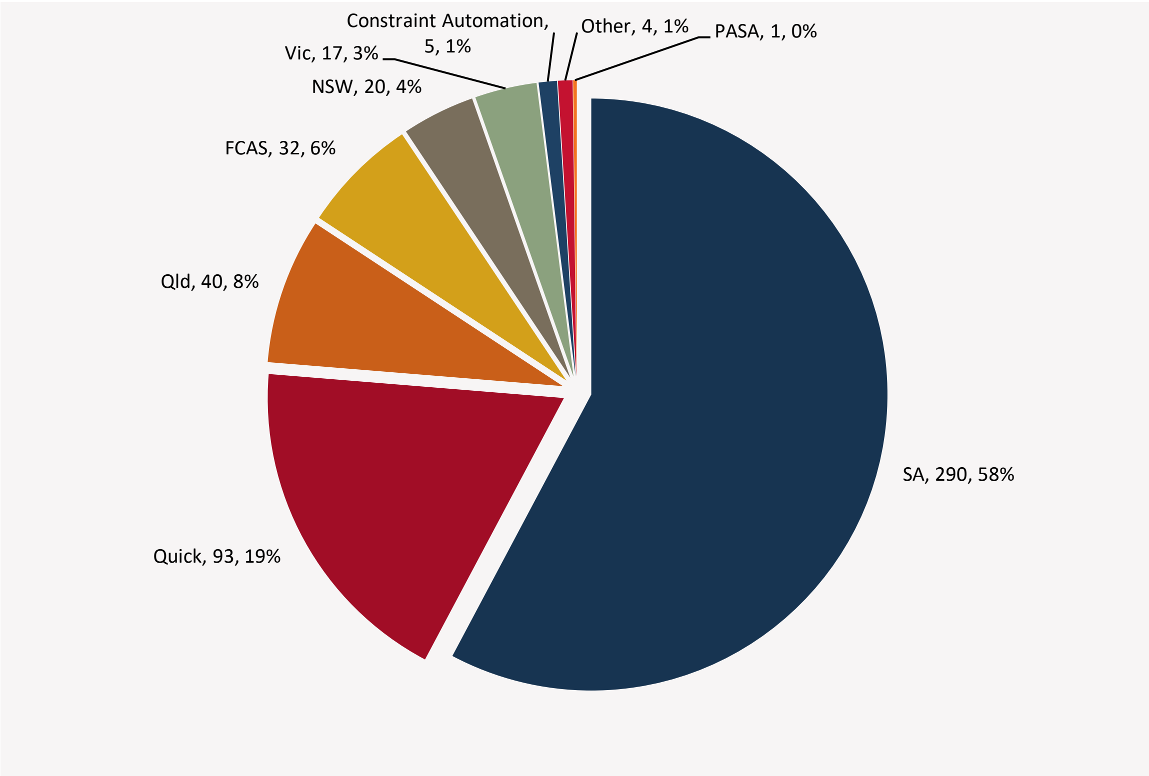
3.1 Constraint Equation Changes

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: https://www.aemo.com.au/energy-systems/market-it-systems/nem-guides/wholesale-it-systems-software

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