Monthly Constraint Report

August 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 August 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.	4679 (389.91)	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)	2128 (177.33)	Other
Q_NIL_STRGTH_HAUSF	Out = Nil, limit Haughton 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.	1693 (141.08)	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	1539 (128.25)	Thermal
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	1362 (113.5)	Voltage Stability
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.	1259 (104.91)	System Strength
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	1164 (97.0)	Thermal
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	1073 (89.41)	System Strength

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1073 (89.41)	Voltage Stability
V_MURRAWRWF_FLT_0	Limit Murra Warra Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	1036 (86.33)	System Strength

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
Q_NIL_STRGTH_HAUSF	Out = Nil, limit Haughton 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.	1,624,128	System Strength
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.	1,229,161	System Strength
V_MURRAWRWF_FLT_0	Limit Murra Warra Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	1,052,970	System Strength
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	954,462	Voltage Stability
N_COLEASF1_FLT_45	Limit Coleambally solar farm upper limit to 45 MW to manage post contingent voltage oscillation	823,247	System Strength
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	717,454	Thermal
V_KARADSF_FLT_25	Limit Karadoc solar farm upper limit to 25 MW to manage post contingent voltage oscillation	693,706	System Strength
V_KIAMSF_FLT_50	Limit Kiamal solar farm upper limit to 50 MW to manage post contingent voltage oscillation	686,431	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
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	680,618	Voltage Stability
N_BROKENHSF_FLT_25	Limit Broken Hill Solar Farm upper limit to 25 MW to manage post contingent voltage oscillation	659,926	System Strength

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
V_COHUNASF_0INV	Constraint to violate if Cohuna Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	37 (3.08)	System Strength
T>T_BUSH1_220	Out = Burnie to Sheffield 220kV line, West Coast 220/110 kV parallel open, avoid O/L a Sheffield 220/110kV transformer for loss of the other Sheffield 220/110kV transformer	11 (0.91)	Thermal
N_BROKENH1_0INV	Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	9 (0.75)	System Strength
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	7 (0.58)	Network Support
NC_V_STOCKYD1	Non Conformance Constraint for STOCKYARD HILL	4 (0.33)	Non-Conformance
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	4 (0.33)	Thermal
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	3 (0.25)	Network Support
V_KIAMAL_0INV	Constraint to violate if Kiamal Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	3 (0.25)	System Strength
Q_STR_7C8C_DAYSF	Limit Daydream SF output to 80% if Stan>=3+Cal>=2+Glad>=2+ (Stan+Cal+Glad) >=8, Kareeya>=2,NQLD>450&470(AVG),Ross_FN>250&270(AVG)(Strathmore SVC OS if Kar=0),60% if (Stan+Cal+Glad) >=7, 40% if ,NQLD>350&370(AVG),Ross_FN>150&170(AVG), Zero otherwise.	3 (0.25)	System Strength
Q_STR_7C8C_HAYSF	Limit Hayman SF output to 80% if Stan>=3+Cal>=2+Glad>=2+ (Stan+Cal+Glad) >=8, Kareeya>=2,NQLD>450&470(AVG),Ross_FN>250&270(AVG)(Strathmore SVC OS if Kar=0),60% if (Stan+Cal+Glad) >=7, 40% if ,NQLD>350&370(AVG),Ross_FN>150&170(AVG), Zero otherwise.	3 (0.25)	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
V_COHUNASF_0INV	Constraint equation violated for 37 non-consecutive DIs with violation degree of 0.01 MW. Constraint equation violation occurred due to Cohuna Solar Farm exceeding its inverter limit.
T>T_BUSH1_220	Constraint equation violated for 11 non-consecutive DIs with max violation of 15.08 MW occurring on 18/08/2021 at 0905 hrs. Constraint equation violation occurred due to Devils Gate being unavailable.
N_BROKENH1_0INV	Constraint equation violated for 9 non-consecutive DIs with violation degree of 0.01 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit.
NSA_V_NPSD_100	Constraint equation violated for 7 non-consecutive DIs with max violation of 59.5 MW occurring on 30/08/2021 at 0105 hrs. Constraint equation violation occurred due to Newport unit being limited by its start-up profile.
NC_V_STOCKYD1	Constraint equation violated for 4 DIs on 01/08/2021 with max violation of 13.99 MW. occurring on 01/08/2021 at 0815 hrs. Constraint equation violation occurred due to Stockyard Hill windfarm non-conforming
S>NIL_MHNW1_MHNW2	Constraint equation violated for 4 DIs on 05/08/2021 with max violation of 3.16 MW occurring at 1030 hrs. Constraint equation violation occurred due to competing import constraint I_CTRL_ISSUE_ML.
NSA_Q_BARCALDN	Constraint equation violated for 3 DIs on 19/08/2021 at 1015 hrs, 1020 hrs and 1145 hrs with max violation of 10.87 MW occurring at 1015 hrs. Constraint equation violation occurred due to Barcaldine GT non-conforming.
V_KIAMAL_0INV	Constraint equation violated for 3 DIs on 10/08/2021 at 1935 hrs, 1940 hrs and 1945hrs with violation degree of 0.01 MW. Constraint equation violation occurred due to Kiamal Solar Farm exceeding its inverter limit
Q_STR_7C8C_DAYSF	Constraint equation violated for 3 DIs on 19/08/2021 at 0920 hrs, 1110 hrs and 1250 hrs with violation degree of 0.001 MW. Constraint equation violation occurred due to Daydream Solar Farm exceeding MVar Limit.
Q_STR_7C8C_HAYSF	Constraint equation violated for 3 DIs on 19/08/2021 at 0920 hrs, 1115 hrs and 1255 hrs with violation degree of 0.001 MW. Constraint equation violation occurred due to Hayman Solar Farm exceeding MVar 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_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1907 (158.92)	407.68 (459.02)

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	1678 (139.83)	408.09 (459.01)
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	1511 (125.92)	146.73 (171.11)
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	1300 (108.33)	145.39 (1064.24)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1040 (86.67)	860.75 (1219.69)
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	864 (72.0)	106.0 (-155.93)
N_MBTE1_B	N-Q-MNSP1 Import	Out= one Directlink cable, Qld to NSW limit	582 (48.5)	-124.07 (-161.4)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	579 (48.25)	379.83 (459.01)
F_MAIN++RREG_0220	T-V-MNSP1 Export	Mainland Raise Regulation Requirement greater than 200 MW, Basslink able transfer FCAS	570 (47.5)	439.66 (459.01)
N^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	559 (46.58)	-386.79 (-781.48)

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

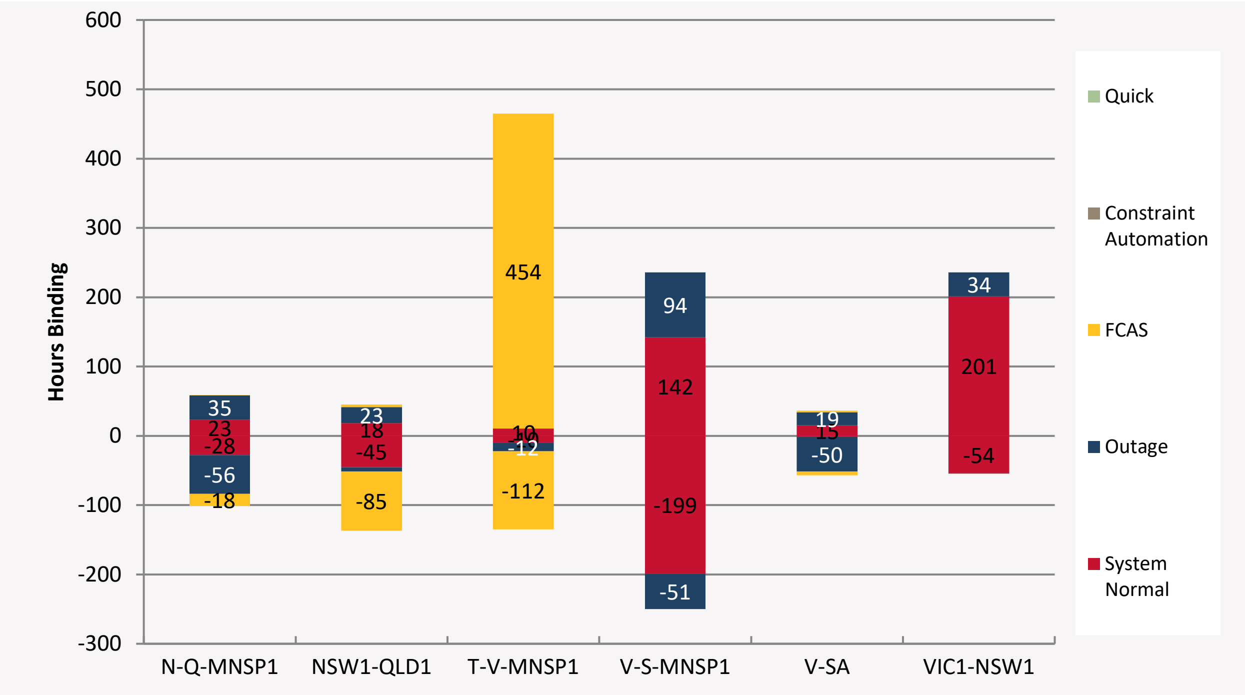
Non-real time constraint automation was not used.

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.

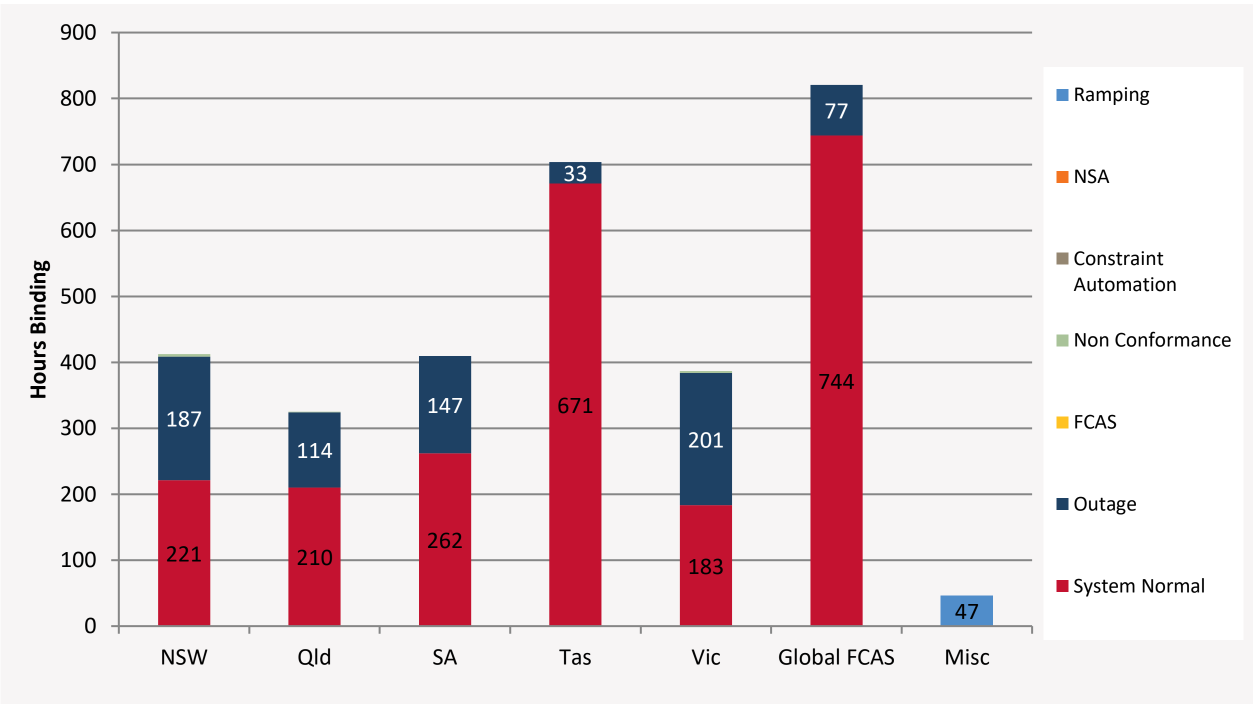
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

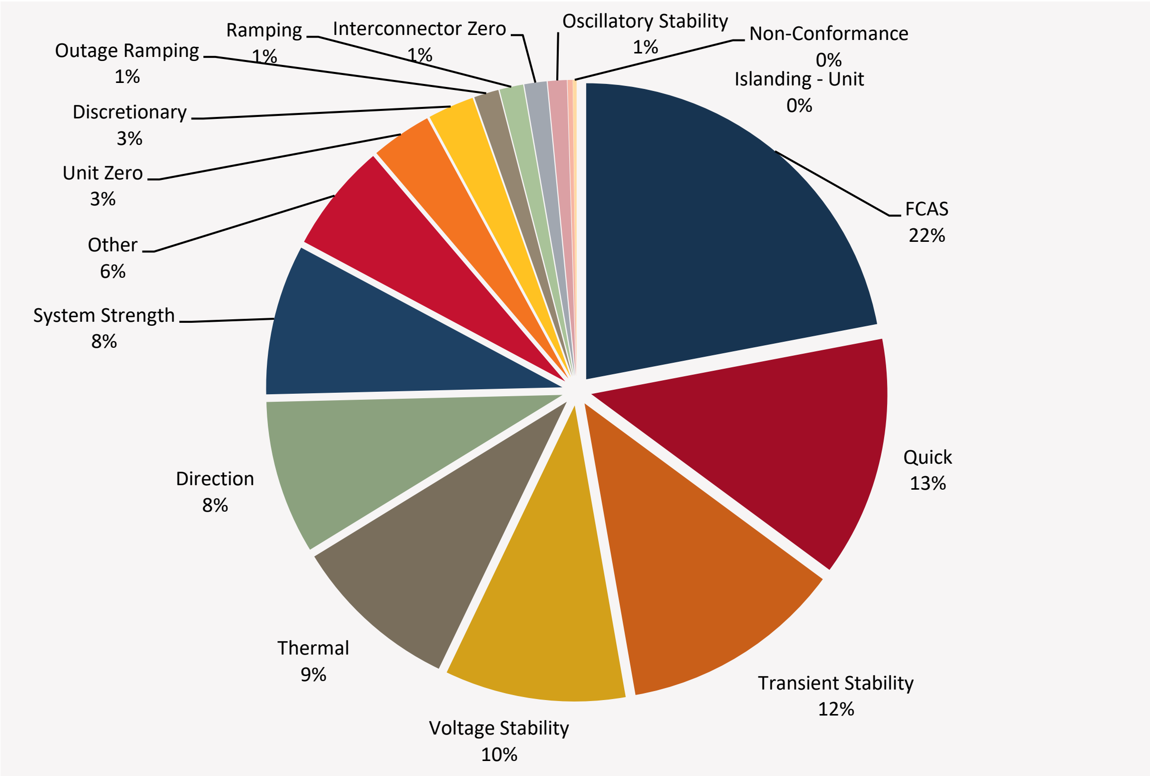
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

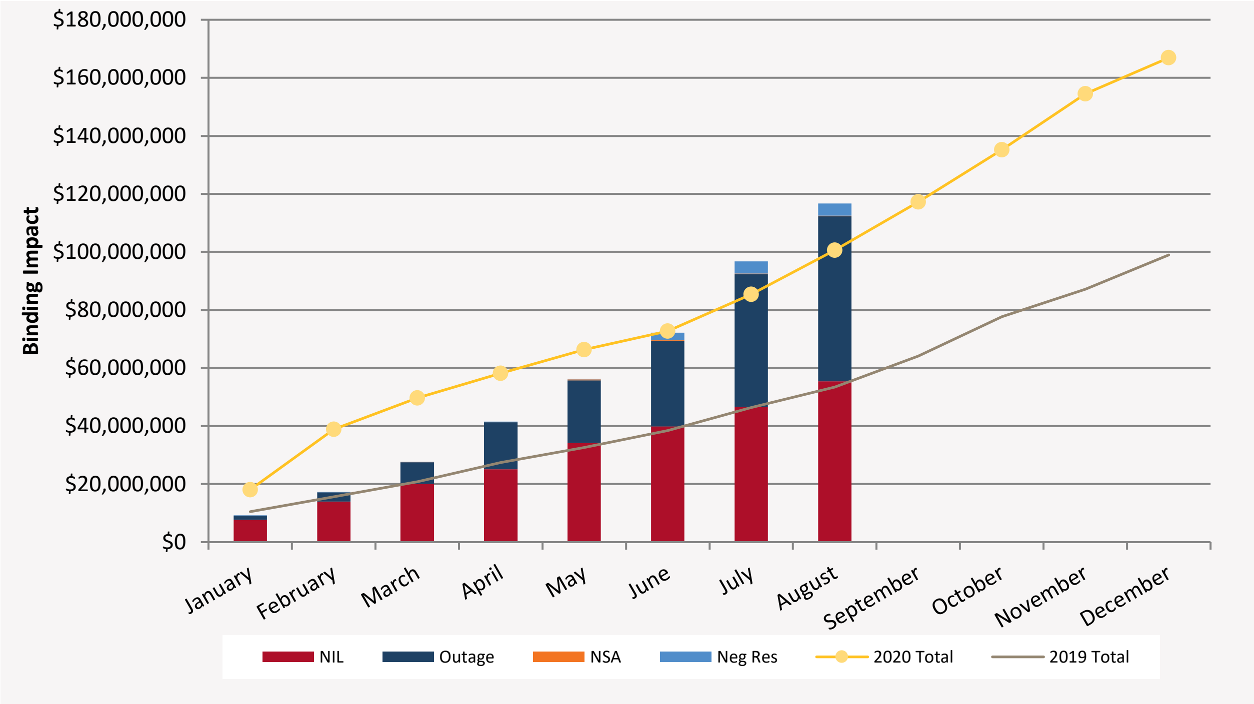
Figure 3 Binding by limit type



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_BEKG_4	Out = Bendigo to Kerang 220kV line, avoid voltage collapse for loss of Ballarat to Waubra to Ararat 220kV line	51	79,700% (249.88)	2,551% (99.02)
V>SMLBAHO1	Out = Bendigo to Kerang line, avoid O/L or voltage collapse on Balranald to Buronga (X3) line for trip of any 220kV line section between Ballarat and Horsham	6	21,427% (64.88)	3,651% (22.66)
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	8	2,398% (98.08)	358% (37.8)
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	18	2,371% (116.04)	332% (70.04)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	13	2,270% (22.9)	240% (8.37)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	3	2,270% (22.7)	869% (12.76)
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.	30	1,842% (9,485)	151% (712)
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.	3	1,305% (243.87)	553% (206.82)
V::N_BEKG_V1	Out = Bendigo to Kerang 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	15	1,075% (450.41)	414% (230.06)
V::N_BEKG_V2	Out = Bendigo to Kerang 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	8	973% (385.)	224% (174.09)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^SML_BEKG_4: Investigated and no improvement can be made to the constraint equation at this stage.

V_S_HEYWOOD_UFLS: Investigated and no improvement can be made to the constraint equation at this stage. Changes to the status of the reactive devices between DS/PD contributes to the PD accuracy.

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 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Mannum Adelaide Pumping Station No 2 Mapl2 (Palmer) - 13.70 Mw Pv Generation	10 August 2021	SA1	New Generator
Armidale No 3 330 kV 50 MVAr Capacitor	19/08/2021	NSW	Part of QNI minor upgrade
Armidale No 4 330 kV 50 MVAr Capacitor	19/08/2021	NSW	Part of QNI minor upgrade
Armidale No 5 330 kV 125 MVAr Capacitor	19/08/2021	NSW	Part of QNI minor upgrade

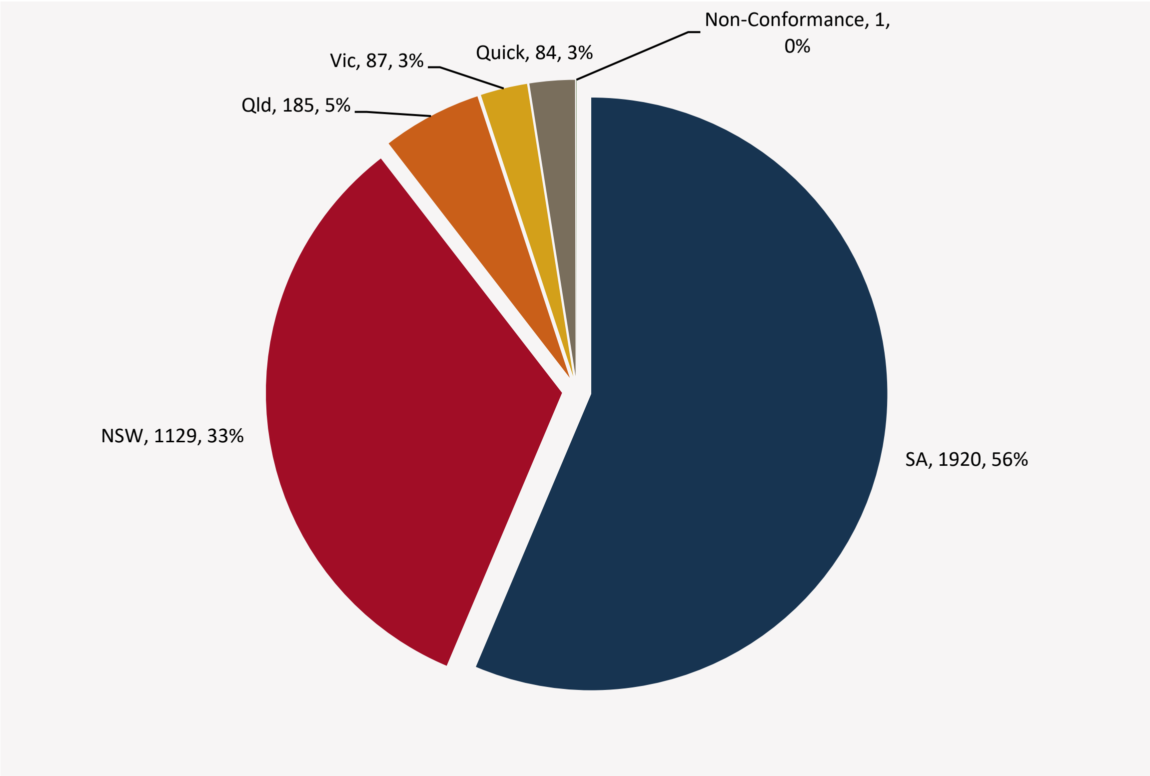
3.1 Constraint Equation Changes

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