AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

July 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 July 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
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.	2979 (248.25)	System Strength
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)	1239 (103.25)	Other
V_STOCKYH_ZERO	Stockyard Hill wind farm upper limit of 0 MW	1144 (95.33)	Unit Zero
V_KARADSF_FLT_20	Limit Karadoc solar farm upper limit to 20 MW to manage post contingent voltage oscillation	1023 (85.25)	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	999 (83.25)	Thermal
V_YATPSF_FLT_20	Limit Yatpool solar farm upper limit to 20 MW to manage post contingent voltage oscillation	975 (81.25)	System Strength
N_LIMOSF1_FLT_60	Limit Limondale 1 solar farm upper limit to 60 MW to manage post contingent voltage oscillation	895 (74.58)	System Strength
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse for contingency trip of Bendigo-Kerang 220kV line in NW Victoria	802 (66.83)	Voltage Stability
N_COLEASF1_FLT_45	Limit Coleambally solar farm upper limit to 45 MW to manage post contingent voltage oscillation	780	System Strength

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
		(65.0)	
V_KIATAWF_FLT_15	Limit Kiata Wind Farm upper limit to 15 MW to manage system stability on the next contingency due to fault level issue	772 (64.33)	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
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.	3,057,865	System Strength
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	1,574,054	Negative Residue
V_KARADSF_FLT_20	Limit Karadoc solar farm upper limit to 20 MW to manage post contingent voltage oscillation	1,098,602	System Strength
F_Q++LDTW_R6	Out = Liddell to Tamworth (84) line, Qld Raise 6 sec Requirement	1,056,040	FCAS
V_YATPSF_FLT_20	Limit Yatpool solar farm upper limit to 20 MW to manage post contingent voltage oscillation	1,044,348	System Strength
N_LIMOSF1_FLT_60	Limit Limondale 1 solar farm upper limit to 60 MW to manage post contingent voltage oscillation	936,653	System Strength
N_COLEASF1_FLT_45	Limit Coleambally solar farm upper limit to 45 MW to manage post contingent voltage oscillation	871,873	System Strength
V_MURRAWRWF_FLT_80	Limit Murra Warra Wind Farm upper limit to 80 MW to manage system stability on the next contingency due to voltage oscillation	789,605	System Strength
N_LIMOSF2_FLT_15	Limit Limondale 2 solar farm upper limit to 15 MW to manage post contingent voltage oscillation	786,980	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_BROKENHSF_FLT_30	Limit Broken Hill Solar Farm upper limit to 30 MW to manage post contingent voltage oscillation	750,761	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

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	89 (7.41)	Negative Residue
V_COHUNASF_0INV	Constraint to violate if Cohuna Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	34 (2.83)	System Strength
V_GANWRSF_0INV	Constraint to violate if Gannawarra Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	19 (1.58)	System Strength
N_DARLSF_FLT_85	Limit Darlington Pt Solar Farm upper limit to 85 MW to manage post contingent voltage oscillation	13 (1.08)	System Strength
NC_V_EILDON2	Non Conformance Constraint for Eildon 2 Power Station	8 (0.66)	Non-Conformance
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.	7 (0.58)	System Strength
NC_V_EILDON1	Non Conformance Constraint for Eildon 1 Power Station	6 (0.5)	Non-Conformance
N_FINLYSF_FLT_50	Limit Finley solar farm upper limit to 50 MW to manage post contingent voltage oscillation	5 (0.41)	System Strength
N_FINLYSF_FLT_45	Limit Finley solar farm upper limit to 45 MW to manage post contingent voltage oscillation	4 (0.33)	System Strength
F_T+NIL_ML_L6	Out = Nil, Lower 6 sec requirement for a Tasmania Load Event, Basslink unable to transfer FCAS	3 (0.25)	FCAS

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
NRM_QLD1_NSW1	Constraint equation violated for 89 non-consecutive DIs on 01/07/2021, 03/07/2021, 21/07/2021 and 23/07/2021 with max violation of 271.83 MW occurring on 03/07/2021 at 0940 hrs. Constraint

Constraint Equation ID (System Normal Bold)	Description
	equation violation occurred due to competing requirements with the export limit which was set by F_Q++LDMU_R6, F_Q++LDMU_R5, F_Q++LDMU_R60 and N>>Q_LDMU_B.
V_COHUNASF_0INV	Constraint equation violated for 34 non-consecutive DIs on 06/07/2021, 15/07/2021, 18/07/2021, 19/07/2021, 26/07/2021 and 27/07/2021 with violation degree 0.001 MW. Constraint equation violation occurred due to Cohuna Solar Farm exceeding its inverter limit.
V_GANWRSF_0INV	Constraint equation violated for 19 non-consecutive DIs on 15/07/2021, 20/07/2021, 24/07/2021 and 26/07/2021 with violation degree of 0.01 MW. Constraint equation violation occurred due to Gannawarra Solar Farm exceeding its inverter limit.
N_DARLSF_FLT_85	Constraint equation violated for 13 non-consecutive DIs on 06/07/2021 and 08/07/2021 with max violation of 65.6 MW occurring on 08/07/2021 at 0905 hrs. Constraint equation violation occurred due to Darlington Pt Solar Farm non-conforming.
NC_V_EILDON2	Constraint equation violated for 8 consecutive DIs on 24/07/2021 from 0900 hrs to 0935 hrs with max violation 8.7 MW occurring at 0920 hrs. Constraint equation violation occurred due to Eildon 2 Power Station non-conforming.
Q_NIL_STRGTH_HAUSF	Constraint equation violated for 7 non-consecutive DIs on 31/07/2021 with violation degree 0.001 MW. Constraint equation violated due to Haughton Solar Farm exceeding MVar limit.
NC_V_EILDON1	Constraint equation violated for 6 consecutive DIs on 24/07/2021 from 0910 hrs to 0935 hrs with max violation of 8.2 MW occurring at 0910 hrs. Constraint equation violation occurred due to Eildon 2 Power Station non-conforming.
N_FINLYSF_FLT_50	Constraint equation violated for 5 DIs on 12/07/2021 with max violation of 27.45 MW occurring at 1430 hrs. Constraint equation violation occurred due to Finley solar Farm non-conforming.
N_FINLYSF_FLT_45	Constraint equation violated for 4 DIs on 15/07/2021 with max violation of 24.1 MW occurring at 1215 hrs. Constraint equation violation occurred due to Finley solar Farm non-conforming.
F_T+NIL_ML_L6	Constraint equation violated for 3 DIs on 27/07/2021 at 1110 hrs and 1130 hrs and on 30/07/2021 at 0245 hrs with violation degree 27.32 MW occurring on 30/07/2021 at 0245 hrs. Constraint equation violated due to Tasmanian lower 6 second availability being less than the requirement.

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	1625 (135.42)	297.95 (446.01)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1350 (112.5)	342.11 (446.01)
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	949 (79.08)	155.15 (176.66)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
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 for contingency trip of Bendigo-Kerang 220kV line in NW Victoria	695 (57.92)	155.73 (1178.96)
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 for contingency trip of Bendigo-Kerang 220kV line in NW Victoria	645 (53.75)	64.31 (-159.44)
V^^N_CNUT_1	VIC1-NSW1 Export	Out = Canberra to Upper Tumut (01) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	588 (49.0)	528.1 (680.78)
V^^N_CNUT_1	V-S-MNSP1 Export	Out = Canberra to Upper Tumut (01) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	579 (48.25)	-69.36 (155.54)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	547 (45.58)	175.67 (446.01)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	529 (44.08)	892.82 (1224.82)
V^^N_CNCW_1	VIC1-NSW1 Export	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W), avoid voltage collapse around Murray for loss of all APD potlines	516 (43.0)	850.56 (1138.43)

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 6 Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_BRIS_50132A69	28/07/2021 10:10 to 28/07/2021 17:55	Constraint automation used to manage OL of Bungama – Redhill – Brinkworth 132kV line at Bungama end on unplanned outage of Waterloo-Hummocks 132kV line, for a loss of the Blyth West – Munno Para 275kV line. ElectraNet confirmed no re-rating available at this stage.

2.5.1 Further Investigation

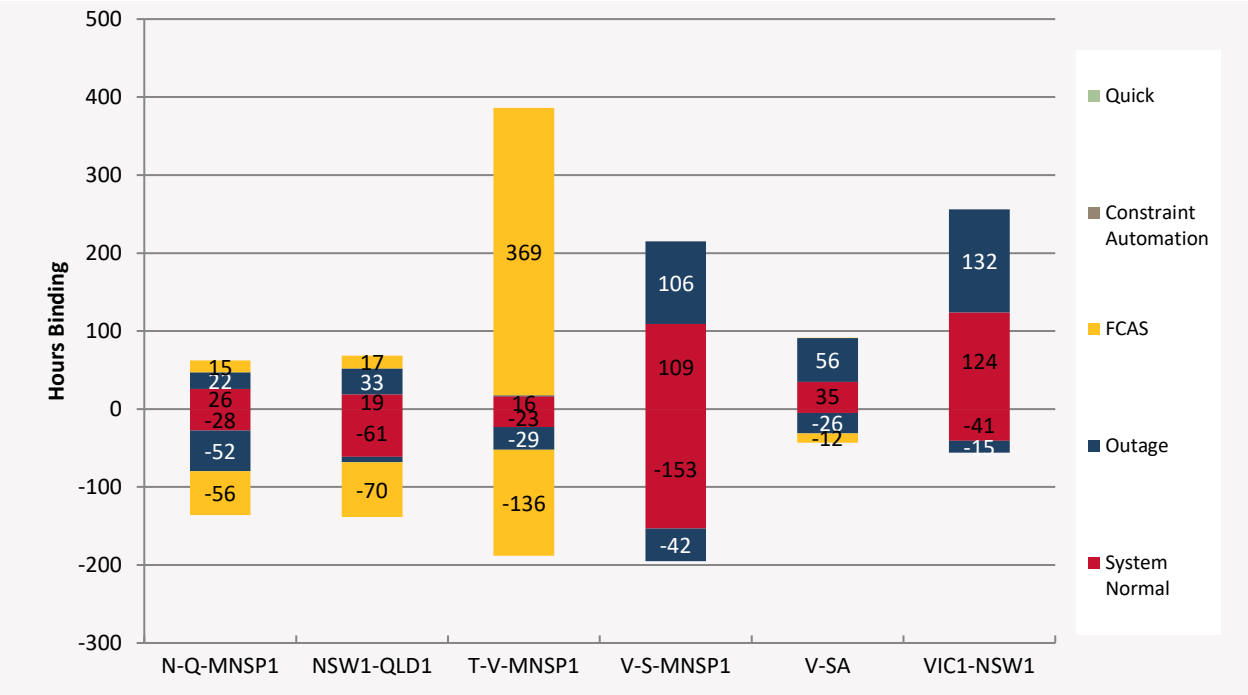
CA_BRIS_50132A69: Control room used constraint automation to prevent overload during an unplanned multiple outage combination. No constraint changes were made as this multiple outage combination is uncommon.

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.

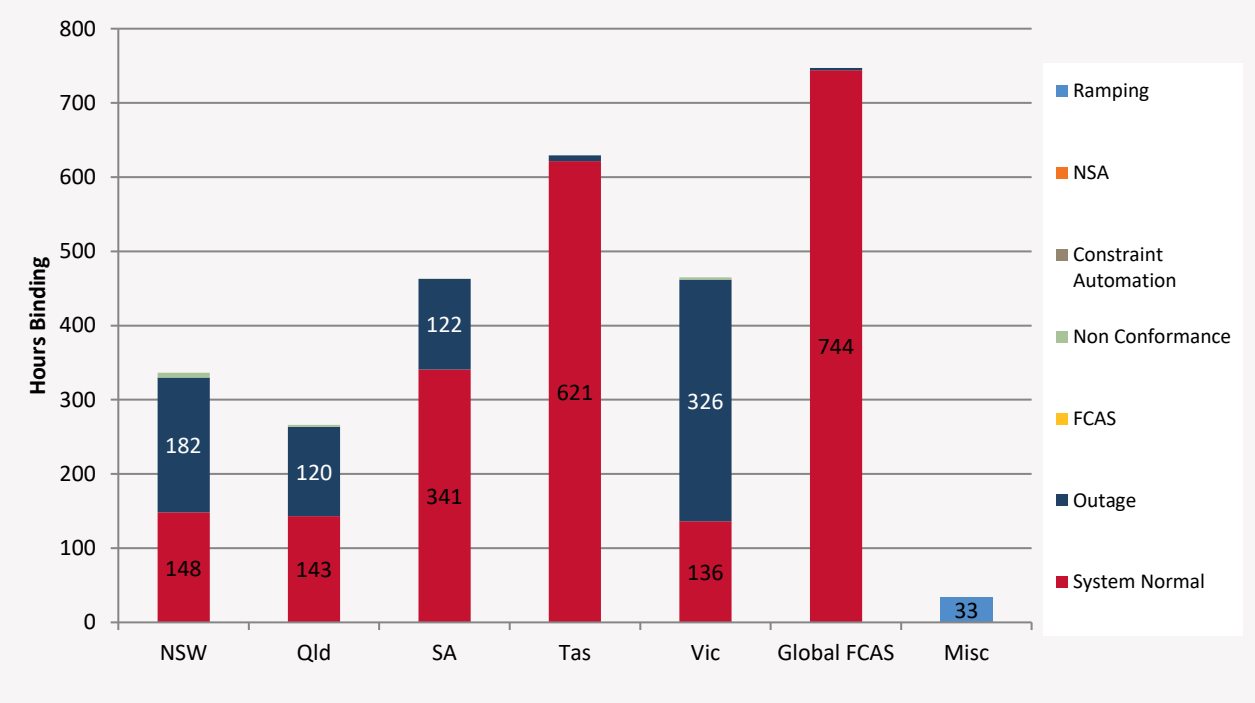
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

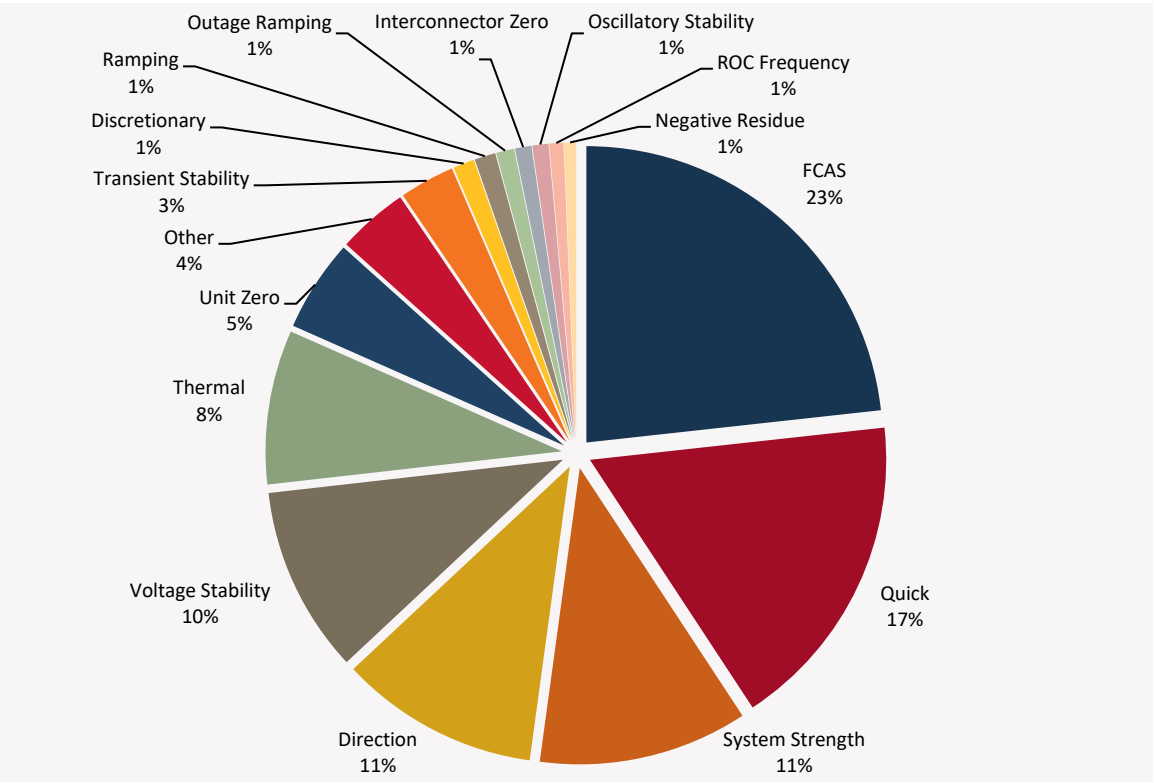
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

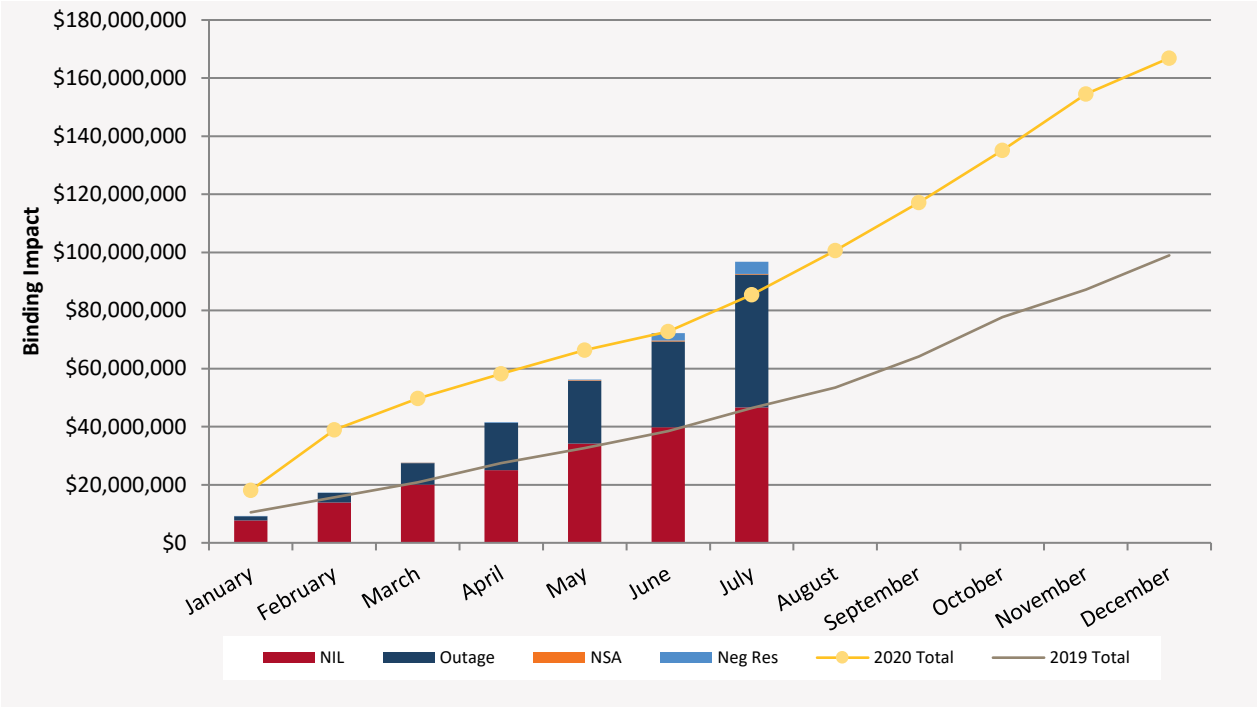
Figure 3 Binding by limit type



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_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	71	164,932% (193.5)	3,962% (70.65)
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	13	19,725% (244.16)	2,475% (108.75)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_KGRC_V1	Out = Kerang to Red Cliffs 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	63	9,882% (367.46)	657% (146.25)
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	9	2,253% (185.78)	329% (56.18)
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.	10	1,603% (9,413)	172% (994)
V::N_HYMO_V1	Out = Heywood to Mortlake 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	12	1,444% (392.03)	703% (257.26)
N>>Q-LDTW_2	Out= Liddell-Tamworth(84), avoid O/L Liddell to Muswellbrook (83) on trip of QLD largest generation, Feedback	9	1,367% (291.55)	539% (166.09)
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.	30	1,118% (31.43)	86.99% (8.68)
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.	555	884% (9,414)	22.72% (319.32)
V^SML_BEKG_4	Out = Bendigo to Kerang 220kV line, avoid voltage collapse for loss of Ballarat to Waubra to Ararat 220kV line	8	711% (112.02)	162% (71.04)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^SML_KGRC_4: Investigated and no improvement can be made to the constraint equation at this stage.

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

V::N_KGRC_V1: Investigated and no improvement can be made to the constraint equation at this stage.

N>>Q-LDTW_2: Investigated and no improvement can be made to the constraint equation at this stage.

V_VS_LB_CAN_50: 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.

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 July 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Bulgana Battery (Generation Component)	1 July 2021	VIC1	New Generator
Bulgana Battery (Load Component)	1 July 2021	VIC1	New Generator
Wandoan South Bess (Generation Component)	6 July 2021	QLD1	New Generator
Wandoan South Bess (Load Component)	6 July 2021	QLD1	New Generator
Stockyard Hill Wind Farm	8 July 2021	VIC1	New Generator
Suntop Solar Farm	27 July 2021	NSW1	New Generator
Victorian Big Battery (Load Component)	27 July 2021	VIC1	New Generator
Victorian Big Battery (Generator Component)	27 July 2021	VIC1	New Generator

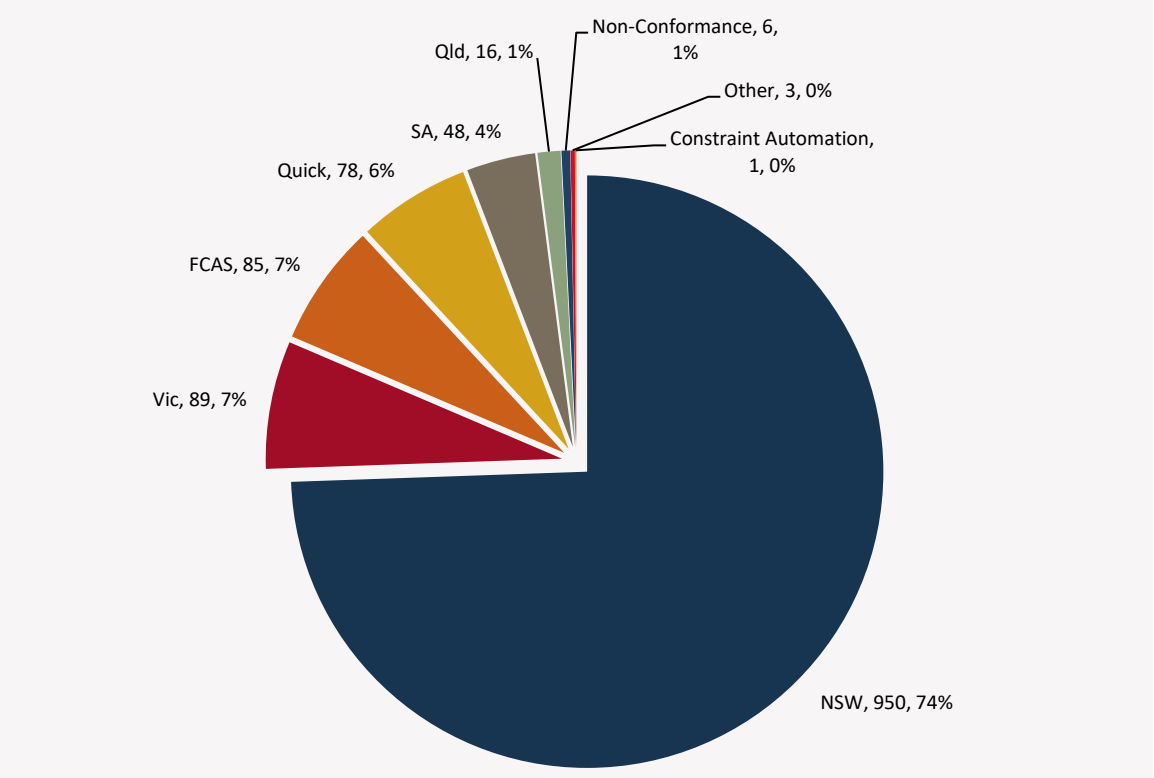
3.1 Constraint Equation Changes

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