Monthly Constraint Report

December 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 December 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
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	5175 (431.25)	Interconnector Zero
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	3242 (270.16)	Thermal
V^^V_MLNK_KGTS	Out= Murraylink, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	2459 (204.91)	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	2441 (203.41)	Voltage Stability
N^^Q_NIL_B1	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	1993 (166.08)	Voltage Stability
N>N-NIL_997_99A	Out= Nil, avoid O/L Corowa to Albury 132kV line (997/1) on trip of Finley to Uranquinty 132kV line (99A), Feedback	1981 (165.08)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1915 (159.58)	Thermal
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1908 (159.0)	Thermal
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1893 (157.75)	Voltage Stability

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
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	1725 (143.75)	Thermal

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_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	5,031,559	Thermal
V^^V_MLNK_KGTS	Out= Murraylink, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	2,815,607	Voltage Stability
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	2,207,146	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	2,028,753	Thermal
N>N-NIL_997_99A	Out= Nil, avoid O/L Corowa to Albury 132kV line (997/1) on trip of Finley to Uranquinty 132kV line (99A), Feedback	1,927,385	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	1,426,464	Voltage Stability
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	1,334,257	Thermal
V_MACWF_FLT_0	Limit Macarthur Wind Farm upper limit to 0 MW to manage post contingent voltage oscillation	885,398	System Strength
N::N_NIL_63	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	557,121	Voltage Stability
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	541,982	Voltage Stability

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

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	23 (1.91)	Thermal
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	19 (1.58)	FCAS
V>V_HWJL4_R_1	Out = Hazelwood to Jeeralang No.4 220kV line OR Hazelwood to Jeeralang No.4 line No.4 bus 220kV CB, avoid O/L MWTS B3 220/66kV txfmr for trip of HWPS A4 500/220kV txfmr, Radial mode, YWG1 on 500kV. Swamp out if YWG1 on 220kV mode	15 (1.25)	Thermal
NSA_V_BDL02_40	Bairnsdale Unit 2 >= 40 MW for Network Support Agreement	7 (0.58)	Network Support
F_T+NIL_MG_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	5 (0.41)	FCAS
NC_Q_KAREEYA4	Non Conformance Constraint for Kareeya 4 Power Station	4 (0.33)	Non-Conformance
N_MOREESF1_0INV	Constraint to violate if Moree Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	4 (0.33)	System Strength
F_T+NIL_MG_R60	Out = Nil, Raise 60 sec requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	3 (0.25)	FCAS
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
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)	FCAS

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
N>>N-NIL_969	Constraint equation violated for 23 DIs, 19 of which were consecutive, on 11/12/2021 at 1025 hrs and 18/12/2021 from 0940 hrs to 1145 hrs with max violation of 19.28 MW occurring on 18/12/2021 at 1015 hrs. Constraint equation violated due to Gunnedah Solar Farm 1 (11/12/2021), and Moree Solar Farm and White Rock Solar Farm (18/12/2021) non-conforming.
F_T_AUFLS2_R6	Constraint equation violated for 19 non-consecutive DIs with max violation of 35.77 MW occurring on 02/12/2021 at 1250 hrs. Constraint equation violated due to Tasmania Raise 6 sec service availability less than requirement.

Constraint Equation ID (System Normal Bold)	Description
V>V_HWJL4_R_1	Constraint equation violated for 15 consecutive DIs on 30/12/2021 from 1540 hrs to 1650 hrs with max violation of 126.4 MW occurring at 1540 hrs. Constraint equation violated due to Yallourn Power Station Unit 1 being limited by its ramp rate following a switch from 220 kV to 500 kV mode.
NSA_V_BDL02_40	Constraint equation violated for 7 DIs, 6 of which were consecutive, on 23/12/2021 at 0705 hrs and 31/12/2021 from 1805 hrs to 1830 hrs with max violation of 40 MW occurring on 31/12/2021 at 1830 hrs. Constraint equation violated due to Bairnsdale Unit 2 non-conforming.
F_T+NIL_MG_R6	Constraint equation violated for 5 non-consecutive DIs on 01/12/2021 at 1040 hrs and 1045 hrs, 02/12/2021 at 0410 hrs, 15/12/2021 at 0825 hrs, and 23/12/2021 at 1020 hrs, with max violation of 27.85 MW occurring on 02/12/2021 at 0410 hrs. Constraint equation violated due to Tasmania raise 6 sec service availability being less than requirement.
NC_Q_KAREEYA4	Constraint equation violated for 4 non-consecutive DIs on 07/12/2021 from 0210 hrs to 0235 hrs with max violation of 0.43 MW occurring at 0235 hrs. Constraint equation violation occurred due to Kareeya unit 4 non-conforming.
N_MOREESF1_0INV	Constraint equation violated for 4 consecutive DIs on 1/12/2021 from 0645 hrs to 0700 hrs with violation degree of 0.001 MW. Constraint equation violation occurred due to Moree Solar Farm exceeding its inverter limit.
F_T+NIL_MG_R60	Constraint equation violated for 3 DIs on 01/12/2021 at 1040 hrs and 1045 hrs, and 23/12/2021 at 1020 hrs, with max violation of 47.93 MW occurring on 01/12/2021 at 1045 hrs. Constraint equation violated due to Tasmania raise 60 sec service availability being less than requirement.
F_T+NIL_ML_L6	Constraint equation violated for 3 DIs on 09/12/2021 from 1350 hrs to 1400 hrs with max violation of 30.23 MW occurring at 1355 hrs. Constraint equation violation occurred due to the Tasmania lower 6 second availability being lower than the requirement.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 3 DIs on 20/12/2021 at 0135 hrs, and 27/12/2021 at 1450 hrs and 1510 hrs, with max violation of 4.67 MW occurring on 27/12/2021 at 1450 hrs. Constraint equation violated due to Tasmania raise 6 sec service availability being less than 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)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	3862 (321.83)	0.0 (0.0)
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	2066 (172.17)	340.87 (948.51)
N^^Q_NIL_B1	NSW1-QLD1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	1985 (165.42)	256.93 (806.7)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1758 (146.5)	795.33 (1226.54)

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	1547 (128.92)	164.47 (217.8)
N^^Q_NIL_B1	N-Q-MNSP1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	1456 (121.33)	31.45 (94.04)
F_MAIN++ML_L6_0400	T-V-MNSP1 Import	Out = Nil, Lower 6 sec requirement for a Mainland Load Event, ML = 400, Basslink able transfer FCAS	1287 (107.25)	-400.8 (-454.01)
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	1225 (102.08)	-388.41 (-454.0)
V^^V_MLNK_KGTS	V-S-MNSP1 Import	Out= Murraylink, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	1164 (97.0)	0.0 (0.0)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	917 (76.42)	133.74 (454.01)

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

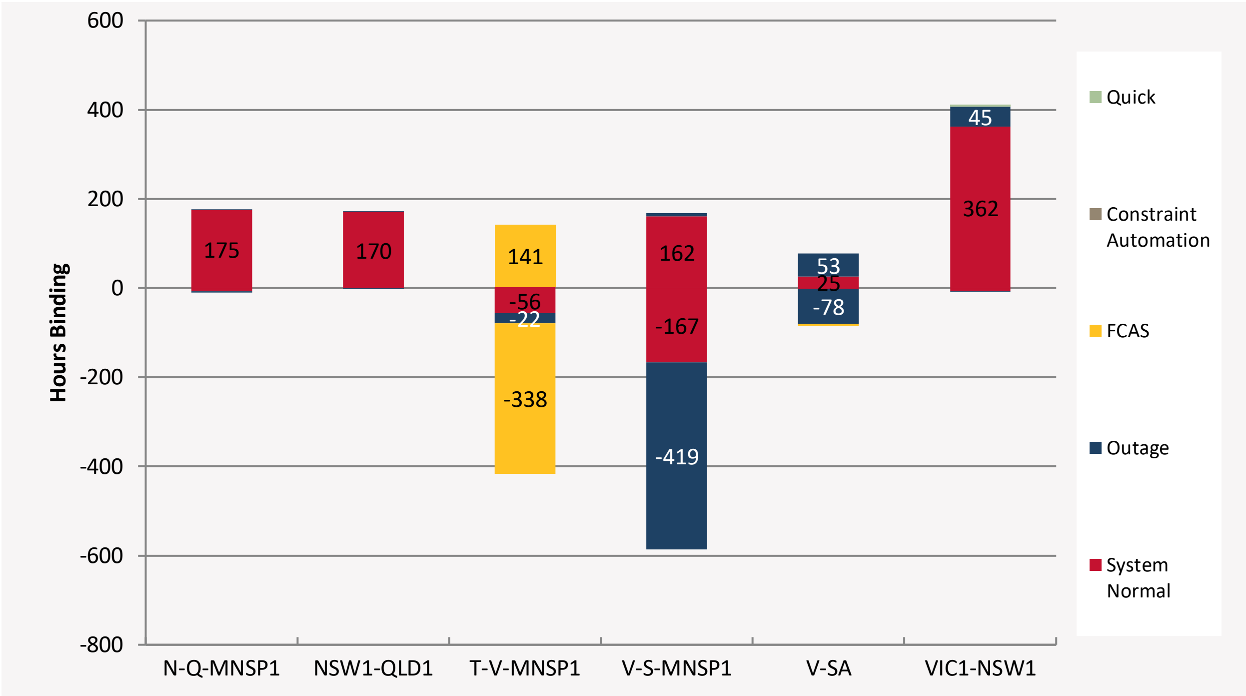
Non-real time constraint automation was not used.

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.

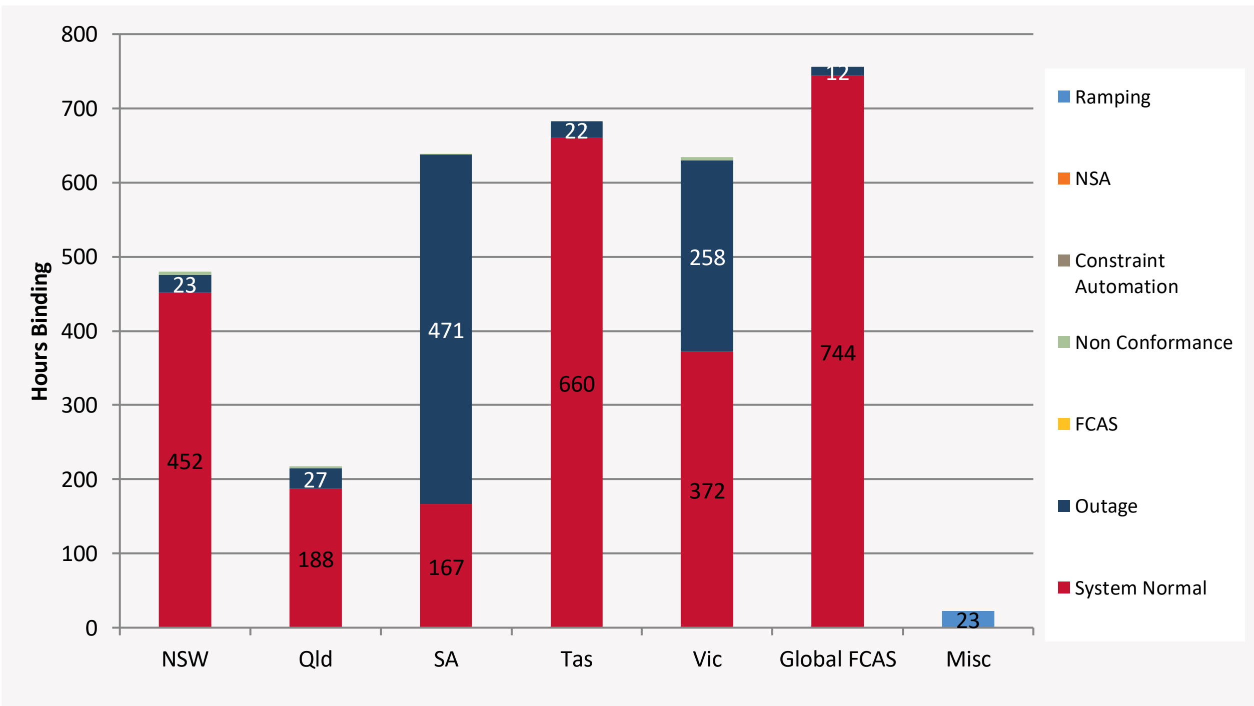
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

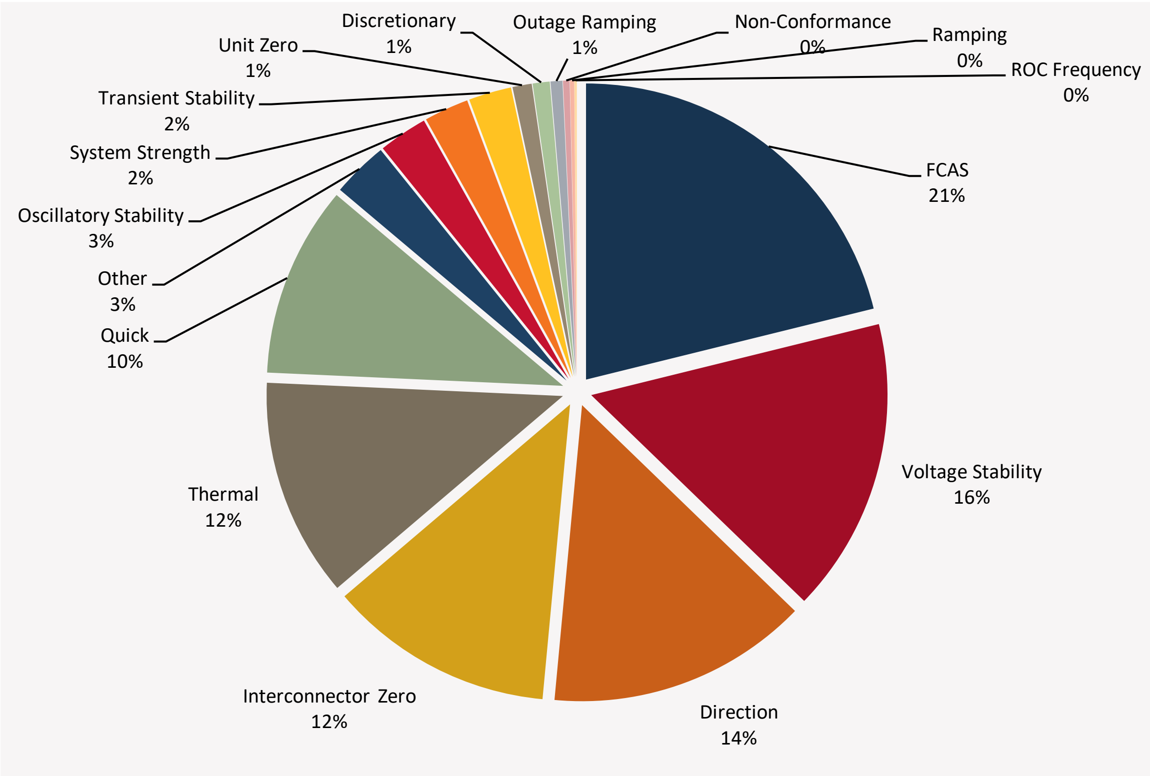
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

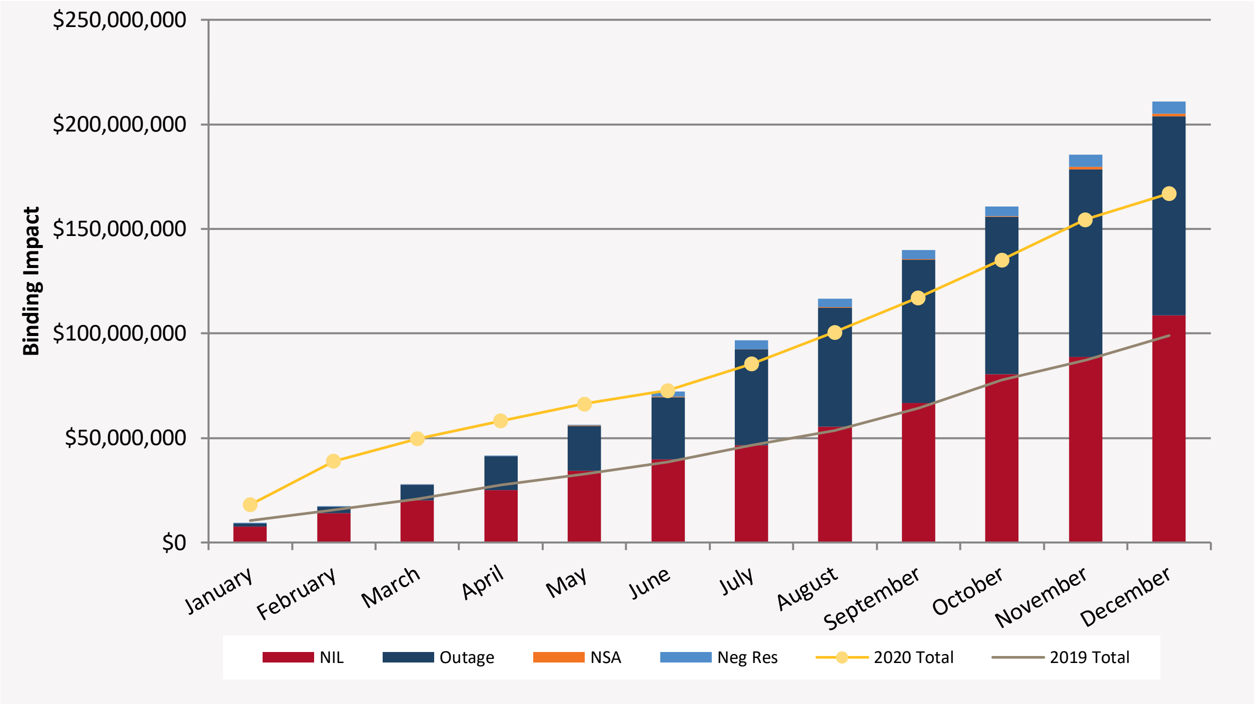
Figure 3 Binding by limit type



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::N_MLSY_S1	Out = Moorabool to Sydenham 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 220 kV.	22	152,832% (290.77)	7,011% (87.25)
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.	92	1,899% (9,500)	446% (1,519)
V::N_MLSY_S2	Out = Moorabool to Sydenham 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	9	1,085% (169.2)	202% (67.95)
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	18	261% (150.08)	81.26% (100.51)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_HYSE_S1	Out = Heywood to South East 275kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 220 kV.	6	246% (217.49)	97.16% (120.13)
V^^SML_NSWRB_2	Out = NSW Murraylink runback scheme, VIC to SA transfer limit on Murraylink to avoid voltage collapse at Red Cliffs for the loss of either the Darlington Point to Balranald (X5) or Balranald to Buronga (X3) 220kV lines	49	142.47% (259.62)	75.67% (160.98)
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.	82	140.37% (285.05)	49.55% (175.44)
V::S_NIL_MAXG_1	Out = Nil(Note: with both Black Range series capacitors I/S); Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available).	41	127.88% (199.15)	31.94% (74.85)
V::N_HYSE_V1	Out = Heywood to South East 275kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	5	119.2% (150.67)	28.12% (47.9)
V::N_MLSY_V1	Out = Moorabool to Sydenham 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	20	117.75% (203.04)	36.27% (94.93)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_HYSE_S1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_MLSY_S1: 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.

V::N_MLSY_S2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_HWSM_S1: Investigated and no improvement can be made to the constraint equation at this stage.

V^^SML_NSWRB_2: Investigated and no improvement can be made to the constraint equation at this stage.

T::T_NIL_1: Investigated and no improvement can be made to the constraint equation at this stage.

V::S_NIL_MAXG_1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_MLSY_V1: 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 December 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Davenport - Port Patterson North 275 kV line	06 December 2021	SA1	Davenport - Port Patterson North 275 kV line was commissioned
Demand Response – Enel X Vic 2	10 December 2021	VIC1	New Generator
Lincoln Gap Stage 2 Wind Farm	14 December 2021	SA1	New Generator
Keilor Terminal Station 100 MVAr 220kV Reactor	17 December 2021	VIC1	At Keilor terminal station the 100 MVAr 220 kV reactor was commissioned on 220 kV Bus 2
Snapper Point Power Station	21 December 2021	SA1	New Generator

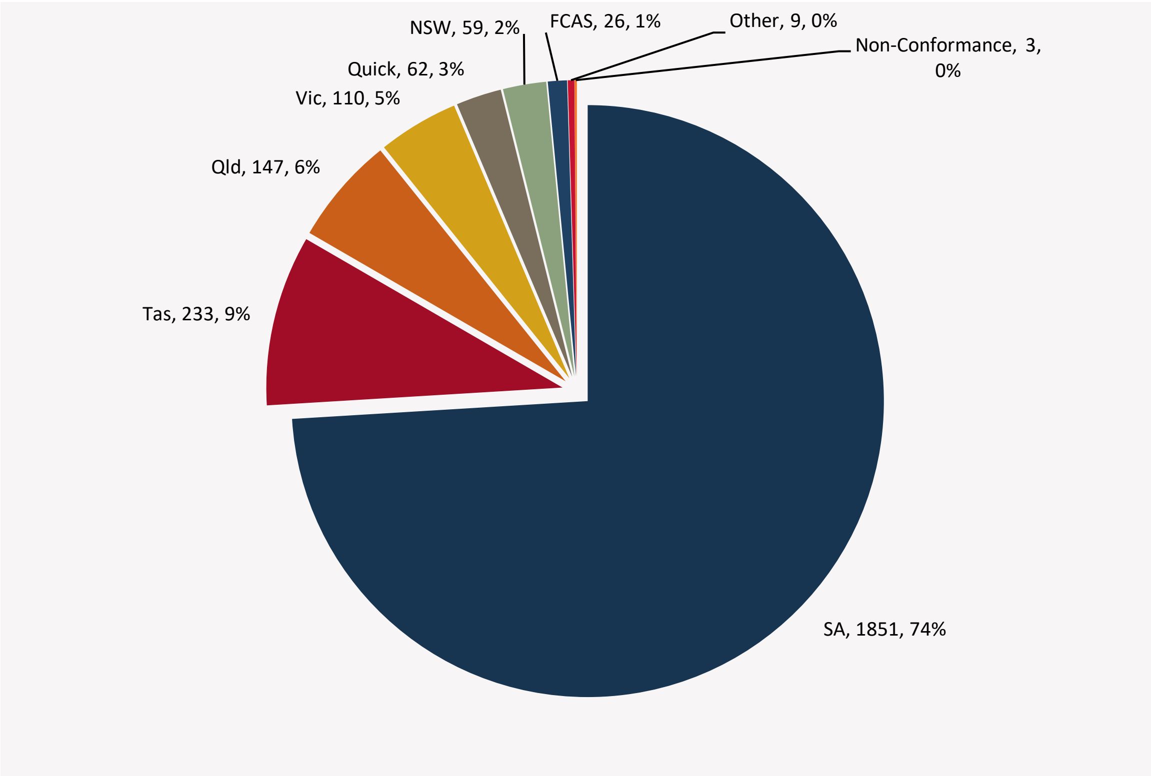
3.1 Constraint Equation Changes

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