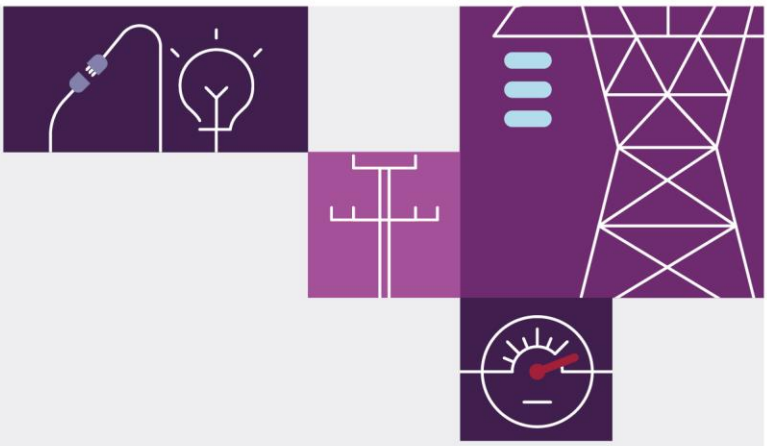
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

March 2023

A report for the National Electricity Market on Constraint results.



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 March 2023. 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
NC_S_BOWWPV1	Non Conformance Constraint for BOLIVAR WWTP PV1	3452 (287.66)	Non-Conformance
Q_STR_7C0K_HASF	No limit to Haughton Solar Farm if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON, Zero otherwise.	3244 (270.33)	System Strength
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	2131 (177.58)	Thermal
N_GOONSF1_ZERO	Goonumbla solar farm upper limit of 0 MW	1728 (144.0)	Unit Zero
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line. Murraylink VFRB disabled. Swamp if Murraylink VFRB enabled.	1664 (138.66)	Voltage Stability
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1649 (137.41)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1434 (119.5)	Thermal
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; [Swamped for three DLK cables are O/S or Swamped when ECS is enabled with DLK is exporting to QLD, sets DLK to -29 MW for -29< DLK FLOW<0)	1390 (115.83)	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	1217 (101.41)	Thermal
N>94K2_94T_NIL	Out= Parkes to Suntop (94K/2) 132kV line (Open at Parkes end only), avoid O/L on Molong to Orange North (94T) on trip of Nil, Feedback	1138 (94.83)	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>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1,921,846	Thermal
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1,639,474	Thermal
N>79_998_72	Out= Wollar West to Wellington (79) 330kV line or Wollar 500/330kV TX or Wollar to Wollar West (75) 330kV line, avoid O/L on Cowra to Forbes North (998) on trip of Mt Piper to Wellington line (72), Feedback	1,411,905	Thermal
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line. Murraylink VFRB disabled. Swamp if Murraylink VFRB enabled.	974,513	Voltage Stability
N>94K2_94T_NIL	Out= Parkes to Suntop (94K/2) 132kV line (Open at Parkes end only), avoid O/L on Molong to Orange North (94T) on trip of Nil, Feedback	932,635	Thermal
N>NIL_9R6_9R5	Out= Nil, avoid O/L Wagga North to Wagga132 (9R6) on trip of Wagga North to Wagga330 (9R5) line, Feedback	858,714	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	830,174	Thermal
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	828,920	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	682,153	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	669,705	Voltage Stability

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

[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.

(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>79_998_72	Out= Wollar West to Wellington (79) 330kV line or Wollar 500/330kV TX or Wollar to Wollar West (75) 330kV line, avoid O/L on Cowra to Forbes North (998) on trip of Mt Piper to Wellington line (72), Feedback	41 (3.41)	Thermal
NC_S_BOWWPV1	Non Conformance Constraint for BOLIVAR WWTP PV1	36 (3.0)	Non-Conformance
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; [Swamped for three DLK cables are O/S or Swamped when ECS is enabled with DLK is exporting to QLD, sets DLK to -29 MW for -29< DLK FLOW<0)	16 (1.33)	Voltage Stability
N_BROKENH1_0INV	Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	6 (0.5)	System Strength
N_WR_30_WT-INV	Constraint to violate if White Rock wind/solar farm wind turbine + inverter availability greater than 30. Dispatch only. swamped out otherwise. DS only.	5 (0.41)	System Strength
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
N_MOREESF1_21INV	Limit Moree Solar Farm upper limit to 0 MW if number of inverter available exceed 21. Constraint swamp out otherwise.	3 (0.25)	System Strength
F_T+NIL_WF_TG_R6	Out= Nil, Tasmania Raise 6 sec requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby, Waddamana to Cattle Hill or Pieman to Granville Harbour line, Basslink unable to transfer FCAS	2 (0.16)	FCAS
N^N_KKLS_1	Out= Koolkhan to Lismore (967), avoid voltage collapse on trip of Coffs Harbour to Lismore (89), swamp out when all 3 Directlink O/S	2 (0.16)	Voltage Stability
N_SAPHWF1_28WT	Constraint to violate if Sapphire WF turbines On greater than 28. 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

Constraint Equation ID (System Normal Bold)	Description
N>79_998_72	The constraint equation violated for 41 non-consecutive DIs from 05/03/2023 1805 hrs to 07/03/2023 1910 hrs with a max violation of 49.22 MW occurring on 06/03/2023 1820 hrs. Constraint violated due to Uranquinty Unit 4 being limited by its ramp down rate and Blowering Hydro bidding at fixed bid.
NC_S_BOWWPV1	The constraint equation violated for 36 non-consecutive DIs from 11/03/2023 1300 hrs to 11/03/2023 1650 hrs with a max violation of 0.17 MW occurring on 11/03/2023 1545 hrs. Constraint violated due to Bolivar WWTP PV1 non-conforming.
N^N-LS_SVC	The constraint equation violated for 16 non-consecutive DIs from 22/03/2023 0805 hrs to 24/03/2023 1635 hrs with a max violation degree of 11.3 MW occurring on 24/03/2023 1240 hrs. Constraint violated due to competing requirements with import limits on the DirectLink interconnector which were set by I_CTRL_ISSUE_TE, N>>NIL_964_84_S and N_X_MBTE_3B.
N_BROKENH1_0INV	The constraint equation violated for 6 non-consecutive DIs on 08/03/2023 at 0705 hrs and 0710 hrs and on 28/03/2023 from 0405 hrs to 0420 hrs with violation degree of 0.001 MW. Constraint equation violation due to Broken Hill Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
N_WR_30_WT-INV	The constraint equation violated for 5 non-consecutive DIs between 01/03/2023 1630 hrs and 22/03/2023 1555 hrs with a violation degree of 0.001. Constraint violated due to White Rock Wind/Solar Farm exceeding its inverter/turbine limit.
F_T+NIL_MG_RECL_R6	The constraint equation violated for 3 non-consecutive DIs between 14/03/2023 0215 hrs and 30/03/2023 0325 hrs with a max violation degree of 28.55 MW occurring on 14/03/2023 0220 hrs. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
N_MOREESF1_21INV	The constraint equation violated for 3 consecutive DIs on 22/03/2023 from 1550 hrs to 1600 hrs with a violation degree of 0.001 MW. Constraint violated due to Moree Solar Farm exceeding their inverter limit.
F_T+NIL_WF_TG_R6	The constraint equation violated for 2 non-consecutive DIs on 01/03/2023 1840 hrs and 17/03/2023 1700 hrs with violation degree of 10.92 MW occurring on 17/03/2023 at 1700 hrs. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
N^N_KKLS_1	The constraint equation violated for 2 non-consecutive DIs on 10/03/2023 at 1430 hrs and 11/03/2023 1220 hrs with a max violation degree of 10.2 MW occurring on 11/03/2023 at 1220 hrs. Constraint equation violated due to competing requirement with Terranora interconnector import limit set by QNTE_ROC.
N_SAPHWF1_28WT	The constraint equation violated for 2 non-consecutive DIs on 21/03/2023 at 1425 hrs and 1435 hrs with a violation degree of 0.001 MW. Constraint violated due to Sapphire WF 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)
N^N-LS_SVC	N-Q-MNSP1 Export	Out= Lismore SVC O/S or reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; [Swamped for three DLK cables are O/S or Swamped when ECS is enabled with DLK is exporting to QLD, sets DLK to -29 MW for -29< DLK FLOW<0)	1359 (113.25)	-50.75 (-29.0)
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	1175 (97.92)	165.88 (199.38)
V^^V_NIL_KGTS	V-S-MNSP1 Import	Out= Nil, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line. Murraylink VFRB disabled. Swamp if Murraylink VFRB enabled.	1036 (86.33)	133.04 (-149.28)
Q>>BCRG_CLWU_BCCP	NSW1-QLD1 Export	Out= Bouldercombe to Raglan (811), avoid O/L Bouldercombe to Calliope River (812) on trip of Calvale to Wurdong (871) line, Feedback	1001 (83.42)	-596.0 (419.95)
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	980 (81.67)	-416.69 (-447.01)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	714 (59.5)	52.43 (447.0)
N>NIL_LSDU	N-Q-MNSP1 Export	Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6), Feedback	714 (59.5)	40.85 (93.34)
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	634 (52.83)	-39.31 (884.53)

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	626 (52.17)	3.41 (447.0)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	580 (48.33)	0.0 (0.0)

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

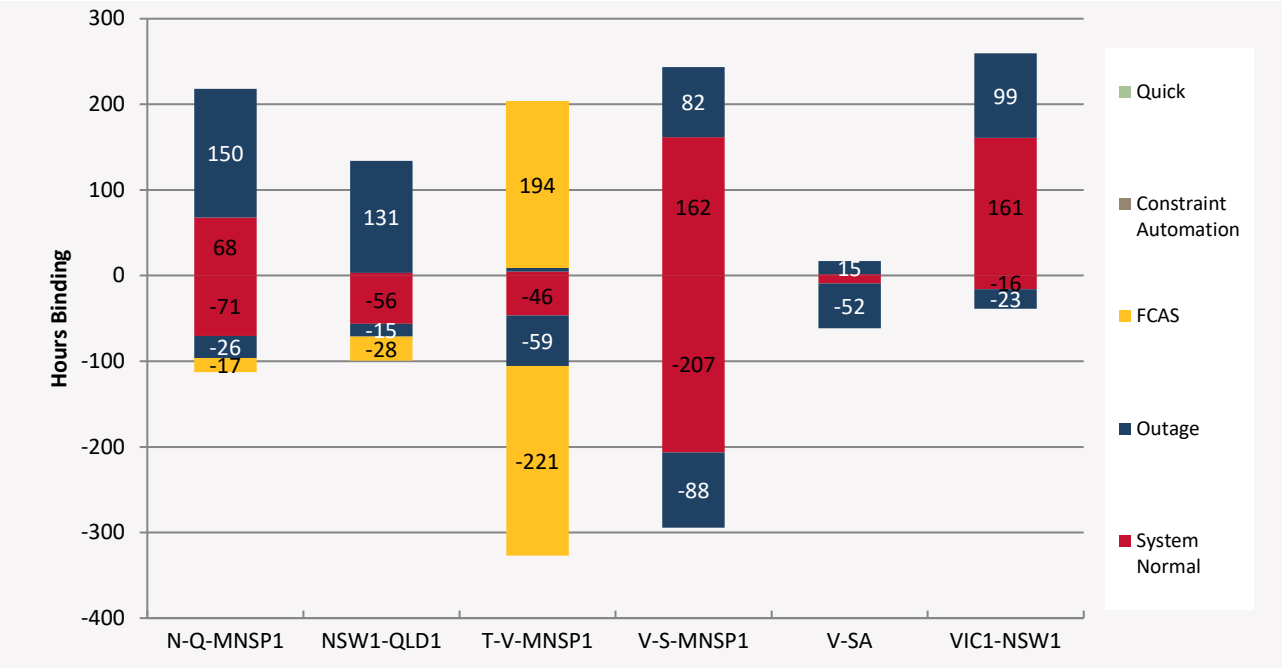
Non-real time constraint automation was not used.

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.

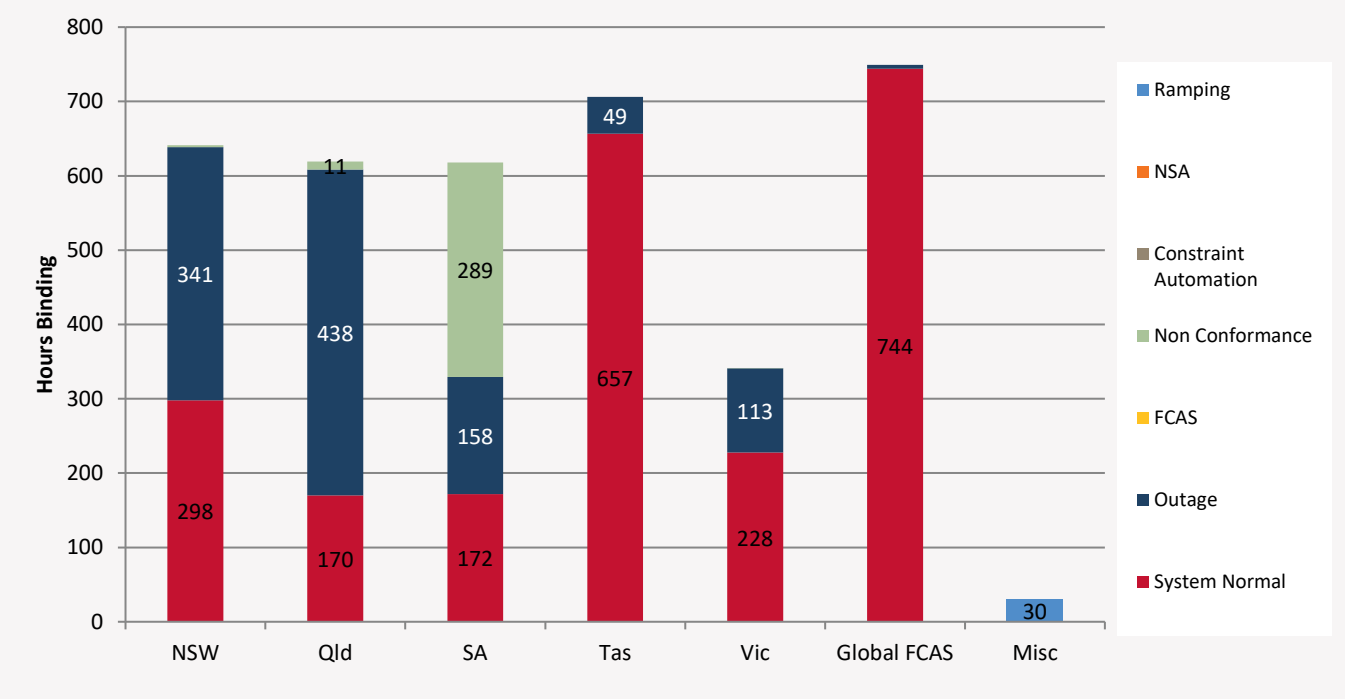
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

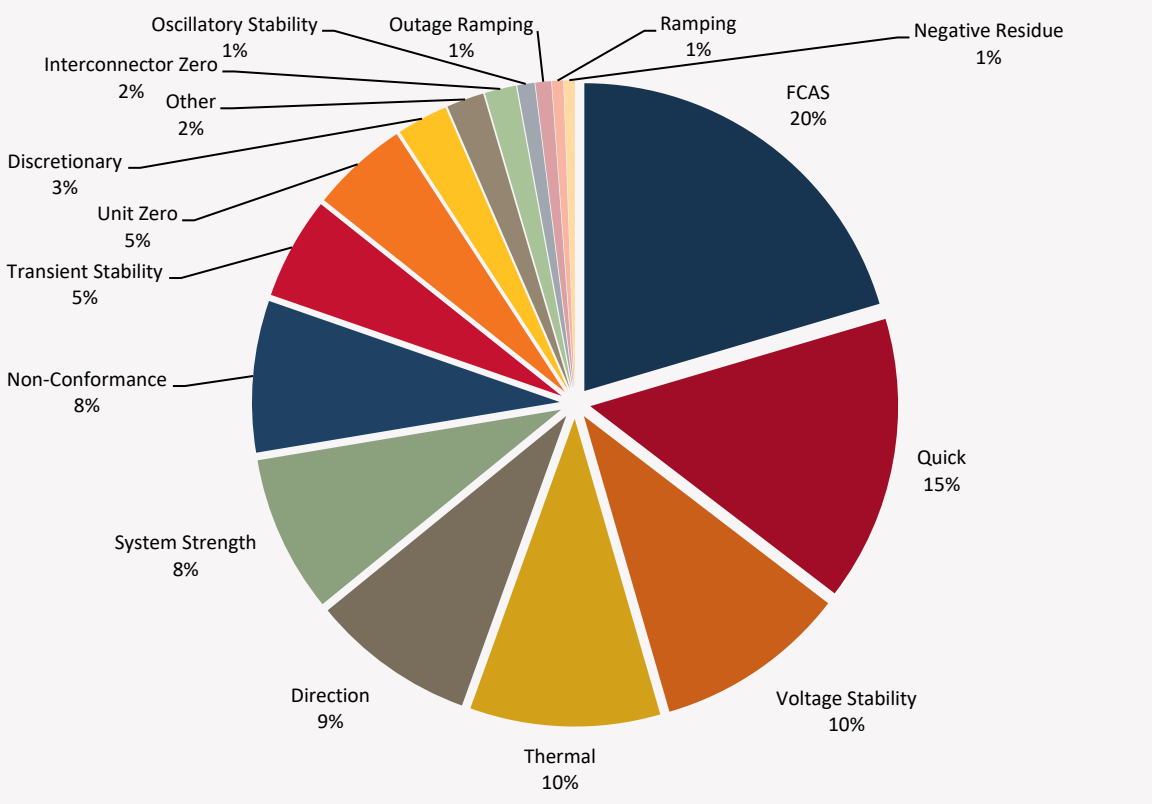
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals for March 2023 that the different types of constraint equations bound.

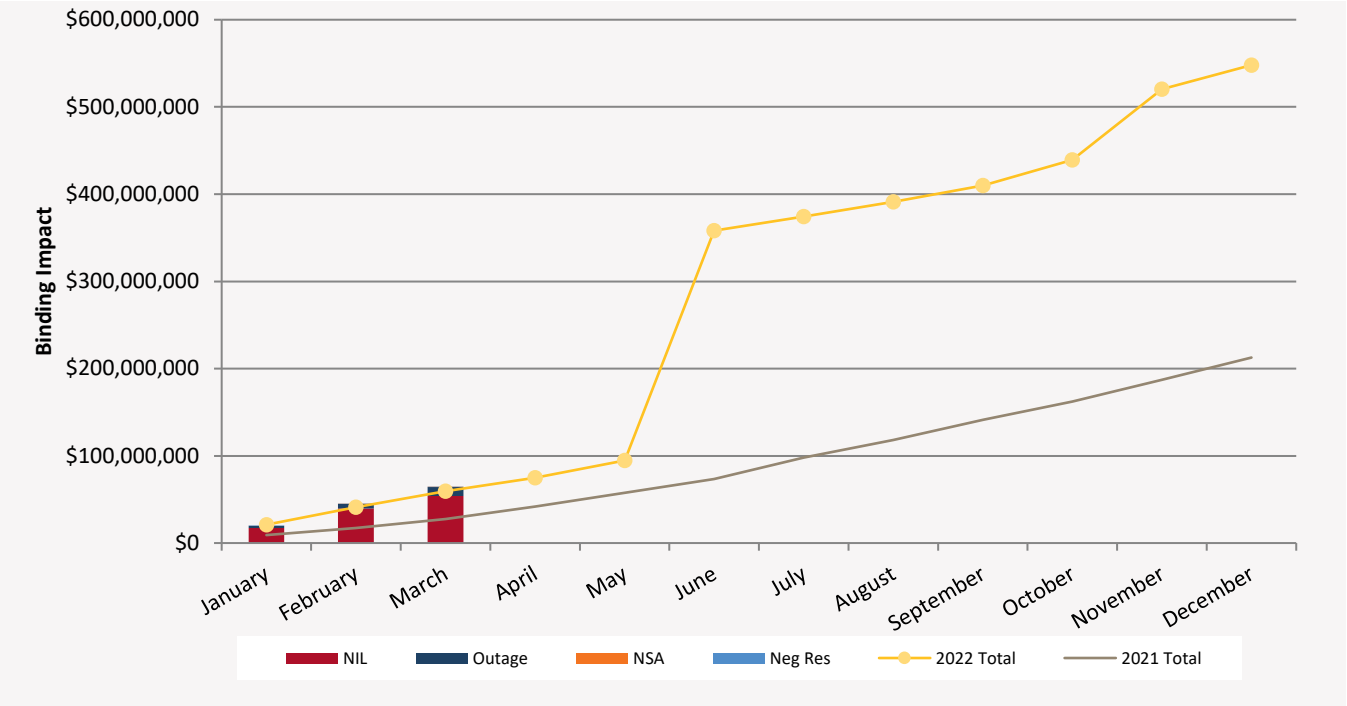
Figure 3 Binding by limit type



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>79_998_72	Out= Wollar West to Wellington (79) 330kV line or Wollar 500/330kV TX or Wollar to Wollar West (75) 330kV line, avoid O/L on Cowra to Forbes North (998) on trip of Mt Piper to Wellington line (72), Feedback	48	826% (87.86)	163% (22.42)
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; [Swamped for three DLK cables are O/S or Swamped when ECS is enabled with DLK is exporting to QLD, sets DLK to -29 MW for -29< DLK FLOW<0)	128	272% (78.92)	37.37% (17.74)
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.	239	183% (347.09)	22.44% (86.48)
N>NIL_LSDU	Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6), Feedback	134	179% (61.13)	41.4% (20.13)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	53	173% (245.97)	39.9% (91.88)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	30	136.67% (28.8)	59.78% (18.41)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	51	134.44% (26.8)	52.89% (12.69)
V::N_X_SMSC_O2	Out = both South Morang 330 kV series capacitor banks, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 500kV.	23	124.89% (332.33)	25.22% (59.86)
N>NIL_999	Out= Nil, avoid O/L Bango999 to Cowra (999) on trip of Nil, Feedback	4	105.19% (176.79)	84.55% (130.49)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N>79_998_72: Investigated and no improvement can be made to the constraint equation at this stage.

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

N>NIL_999: Investigated and constraint equation was updated on 20/02 to improve PD performance.

N^N-LS_SVC: Investigated and constraint equation was updated on 27/08 to improve PD performance.

T::T_NIL_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.

N_X_MBTE_3A: Investigated and the mismatch was due to issues with forecasting of the Terranora load. The forecasting of the Terranora load has been improved in November 2018.

N_X_MBTE_3B: Investigated and the mismatch was due to issues with forecasting of the Terranora load. The forecasting of the Terranora load has been improved in November 2018.

V::N_X_SMSC_O2: 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 March 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Wandoan Solar Farm 1	7 March 2023	QLD	New Generator
Hazelwood PS – Hazelwood BESS 2 220 kV Line	7 March 2023	VIC	
Wollar West substation	21 March 2023	NSW	Wollar West substation has been cut into the existing Wellington - Wollar (79) 330 kV Line to form the following circuits: Wellington - Wollar West 79 330 kV Transmission Line, Wollar - Wollar West 75 330 kV Transmission Line.
Avonlie Solar Farm	28 March 2023	NSW	New Generator
South Morang SMTS F1 transformer 500 / 330 kV	28 March 2023	VIC	Part of VNI minor augmentation
Drillham Substation	29 March 2023	QLD	T280 Drillham substation has been cut into the existing Columboola - Roma 7164 and 7174 132 kV transmission lines to form the following lines: Columboola - Drillham 7490 132 kV line Columboola - Drillham 7491 132 kV line Drillham - Roma 7164 132 kV line Drillham - Roma 7174 132 kV line

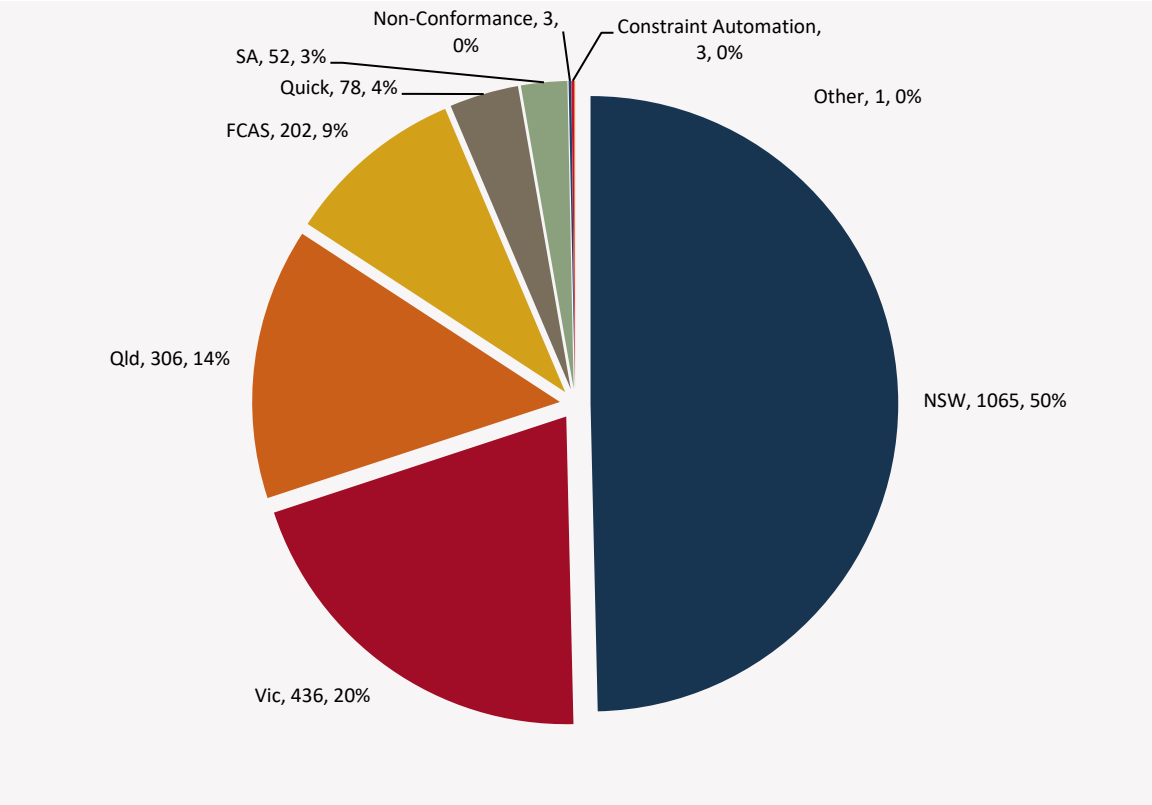
3.1 Constraint Equation Changes

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