Monthly Constraint Report

January 2024

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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Contents

Tables

Figures

1 Introduction

This report details constraint equation performance and transmission congestion related issues for January 2024. 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_MHNW1_MHNW2	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	3116 (259.66)	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2647 (220.58)	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.	2282 (190.16)	Voltage Stability
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	2208 (184.0)	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 [Note: swamped with 96M or 9UJ or 9UH is O/S]	2205 (183.75)	Thermal
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	2161 (180.08)	Voltage Stability
N>NIL_9R6_991	Out= Nil, avoid O/L Wagga North to Wagga (9R6) 132kV line on trip of Wagga North to Murrumburrah (991) 132kV line, Feedback	2084 (173.66)	Thermal
N>>NIL_970_051	Out= NIL, avoid O/L Burrinjuck to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	1651 (137.58)	Thermal
N>NIL_9R4_99A	Out= Nil, avoid O/L Finley to Mulwala 132kV line (9R4) on trip of Finley to Uranquinty (99A) line, Feedback	1634 (136.16)	Thermal
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	1479 (123.25)	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_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	3,750,324	Thermal
N>>NIL_970_051	Out= NIL, avoid O/L Burrinjuck to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	2,412,694	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 [Note: swamped with 96M or 9UJ or 9UH is O/S]	2,223,703	Thermal
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	1,918,364	Thermal
N>NIL_9R6_991	Out= Nil, avoid O/L Wagga North to Wagga (9R6) 132kV line on trip of Wagga North to Murrumburrah (991) 132kV line, Feedback	1,790,942	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	1,759,978	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.	1,673,921	Voltage Stability
N>>NIL_33_34	Out= Nil, avoid Bayswater to Liddell (33 or 34) O/L on loss of other Bayswater to Liddell (34 or 33), Feedback	775,858	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	646,691	Thermal
Q>NIL_TV66	Out=Nil, limit Sun metals SF and Mt Stuart GTs to avoid over load on 66kV feeders on trip of one of the 66kV feeders in the Townsville area	610,894	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

[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
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	24 (2.0)	Negative Residue
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	11 (0.91)	Voltage Stability
N_MOREESF1_40INV	Moree Solar Farm inverter limit of 40. Constraint to violate if Moree Solar Farm inverter availability greater than 40. Swamp out otherwise. DS only	11 (0.91)	System Strength
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	9 (0.75)	Network Support
N_METZSF_38INV	Metz Solar Farm inverter limit of 38. Constraint to violate if Metz Solar Farm inverter availability greater than 38. Swamp out otherwise. DS only	8 (0.66)	System Strength
V_KIAMAL_0INV	Kiamal Solar Farm inverter limit of zero. Constraint to violate if Kiamal Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	5 (0.41)	System Strength
N_BKHSF_44INV	Broken Hill Solar Farm inverter limit of 44. Constraint to violate if Broken Hill Solar Farm inverter availability greater than 44. Swamp out otherwise. DS only	5 (0.41)	System Strength
V_GANNSF_12INV	Gannawarra Solar Farm inverter limit of 12. Constraint to violate if Gannawarra Solar Farm inverter availability greater than 12. Swamp out otherwise. DS only	5 (0.41)	System Strength
V_KARSF_21INV	Karadoc Solar Farm inverter limit of 21. Constraint to violate if Karadoc Solar Farm inverter availability greater than 21. Swamp out otherwise. DS only	5 (0.41)	System Strength
V_BANSF_22INV	Bannerton Solar Farm inverter limit of 22. Constraint to violate if Bannerton Solar Farm inverter availability greater than 22. Swamp out otherwise. DS only	4 (0.33)	System Strength

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
NRM_QLD1_NSW1	Constraint equation violated for 7 consecutive DIs on 21/01/2024 from 1835 hrs to 1905 hrs, and an additional 17 non-consecutive DIs on 18/01/2024 1940 hrs to 26/01/2024 1910 hrs with a max violation degree of 310.32 MW occurring on 21/01/2024 1815 hrs. Constraint equation violated due to competing requirement on the export limits of QNI set by N>>NIL_33_34, and export limits of DirectLink set by N>NIL_LSDU.
N^N-LS_SVC	Constraint equation violated for 11 non-consecutive DIs on 3/01/2024 0925 hrs to 17/01/2024 1325 hrs with a max violation degree of 27.3 MW occurring on 15/01/2024 1205 hrs. Constraint equation violated due to competing requirement on the import limits of DirectLink set by N_X_MBTE_3B.
N_MOREESF1_40INV	Constraint equation violated for 10 consecutive DIs on 2/01/2024 from 1145 hrs to 1230 hrs, and 1 additional DI on 2/01/2024 1600 hrs with a max violation degree of 25.89 MW occurring on 2/01/2024 1600 hrs. Constraint equation violated due to Moree Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
NSA_Q_BARCALDN	Constraint equation violated for 6 consecutive DIs on 4/01/2024 from 0405 hrs to 0430 hrs, and 3 consecutive DIs on 4/01/2024 from 1310 hrs to 1320 hrs with a max violation degree of 13.36 MW occurring on 4/01/2024 1310 hrs, 1315 hrs and 1320 hrs respectively. Constraint equation violated due to Barcaldine GT non-conforming to the Network Service Agreement to meet the local islanded demand requirement.
N_METZSF_38INV	Constraint equation violated for 4 consecutive DIs on 2/01/2024 from 1550 hrs to 1600 hrs, and 5 consecutive DIs on 17/01/2024 from 2135 hrs to 2155 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Metz Solar Farm exceeding its inverter limit.
V_KIAMAL_0INV	Constraint equation violated for 5 consecutive DIs on 7/01/2024 from 1210 hrs to 1230 hrs with a max violation degree of 0.01 MW occurring on all violating DIs. Constraint equation violated due to Kiamal Solar Farm exceeding its inverter limit.
N_BKHSF_44INV	Constraint equation violated for 5 non-consecutive DIs on 7/01/2024 1210 hrs to 7/01/2024 1350 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Broken Hill Solar Farm exceeding its inverter limit.
V_GANNSF_12INV	Constraint equation violated for 5 consecutive DIs on 7/01/2024 from 1210 hrs to 1230 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Gannawarra Solar Farm exceeding its inverter limit.
V_KARSF_21INV	Constraint equation violated for 5 consecutive DIs on 7/01/2024 from 1210 hrs to 1230 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Karadoc Solar Farm exceeding its inverter limit.
V_BANSF_22INV	Constraint equation violated for 4 consecutive DIs on 7/01/2024 from 1210 hrs to 1230 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Bannerton 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)
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	3059 (254.92)	167.15 (216.02)
N^N-LS_SVC	N-Q-MNSP1 Export	Out= Lismore SVC O/S or reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	2022 (168.5)	-56.46 (-29.0)
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.	1887 (157.25)	156.68 (-125.25)
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	1835 (152.92)	-430.71 (-453.0)
N>>NIL_970_051	VIC1-NSW1 Export	Out= NIL, avoid O/L Burrinjuck to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	1385 (115.42)	-60.99 (871.21)
F_MAIN++LREG_0210	T-V-MNSP1 Import	Mainland Lower Regulation Requirement greater than 210 MW, Basslink able transfer FCAS	1294 (107.83)	-429.27 (-453.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
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	1178 (98.17)	32.19 (96.73)
F_MAIN++BIP_ML_L1	T-V-MNSP1 Import	Out = Nil, Lower 1 sec requirement for a Mainland Load Event, for loss of the largest Boyne Island potline, Basslink able transfer FCAS. Requirement capped at 100 MW	1061 (88.42)	-445.72 (-453.0)
N^^Q_LS_SVC_KPP_1	NSW1-QLD1 Export	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage Collapse on loss of Kogan Creek MW	1039 (86.58)	554.93 (749.77)
N>>NIL_33_34	NSW1-QLD1 Export	Out= Nil, avoid Bayswater to Liddell (33 or 34) O/L on loss of other Bayswater to Liddell (34 or 33), Feedback	1025 (85.42)	267.22 (744.39)

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 1 – Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_SYDS_549FBEF5	29/12/2023 16:55 to 03/01/2024 14:20	CA_SYDS_549FBEF5 was created to manage DirectLink to prevent overloading on Mudgeeraba 1T for loss of 5T.

2.5.1 Further Investigation

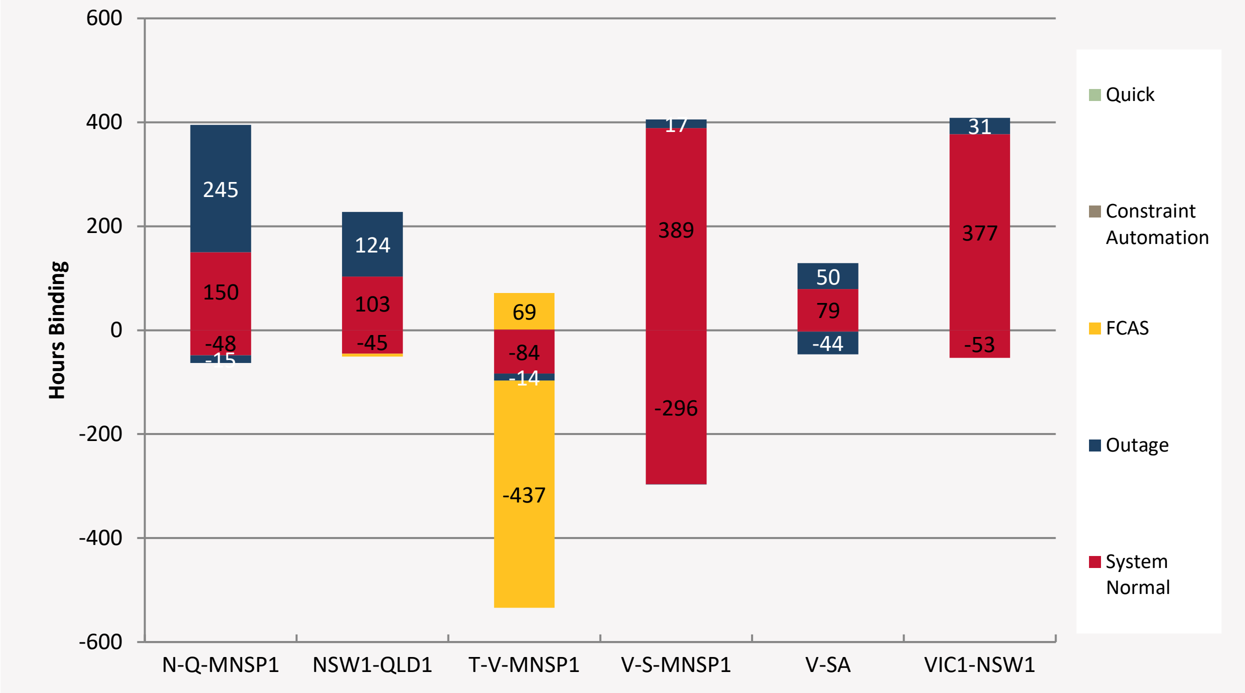
CA_SYDS_549FBEF5: Please refer to December 2023 Constraint report for further investigation.

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.

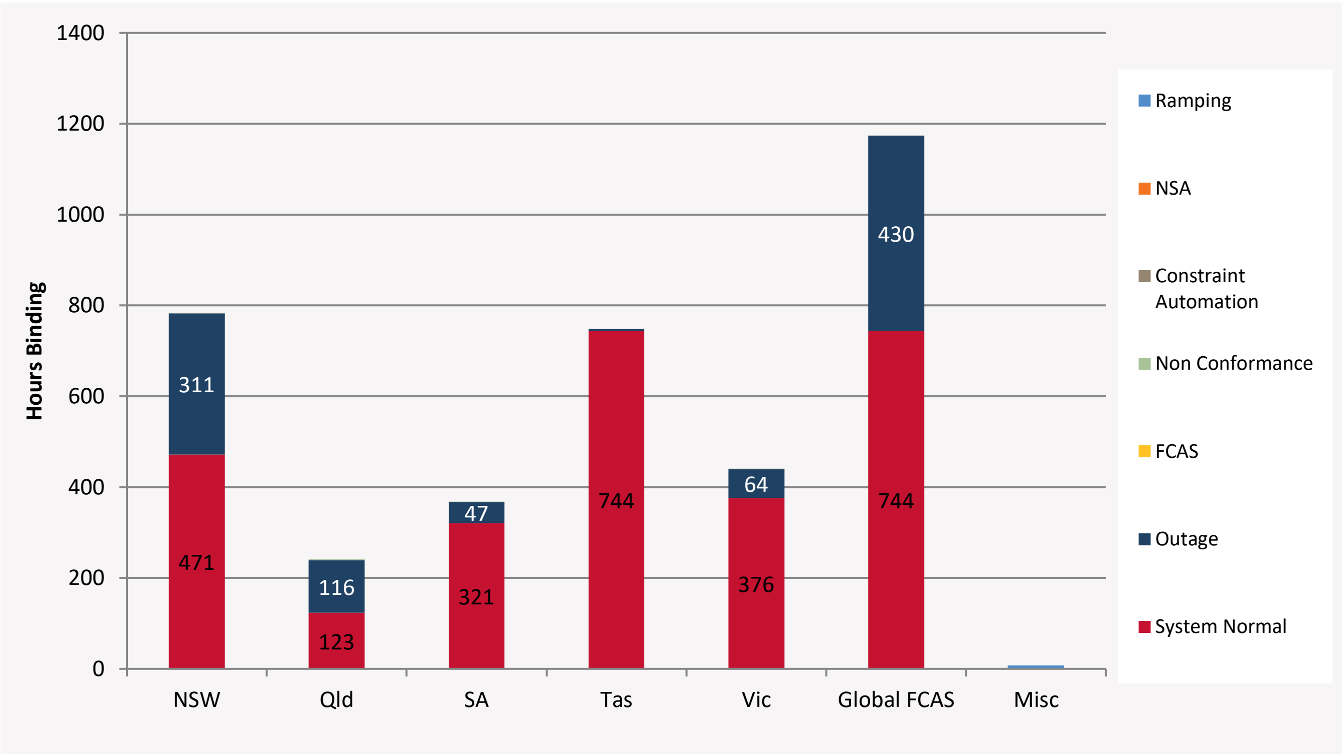
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

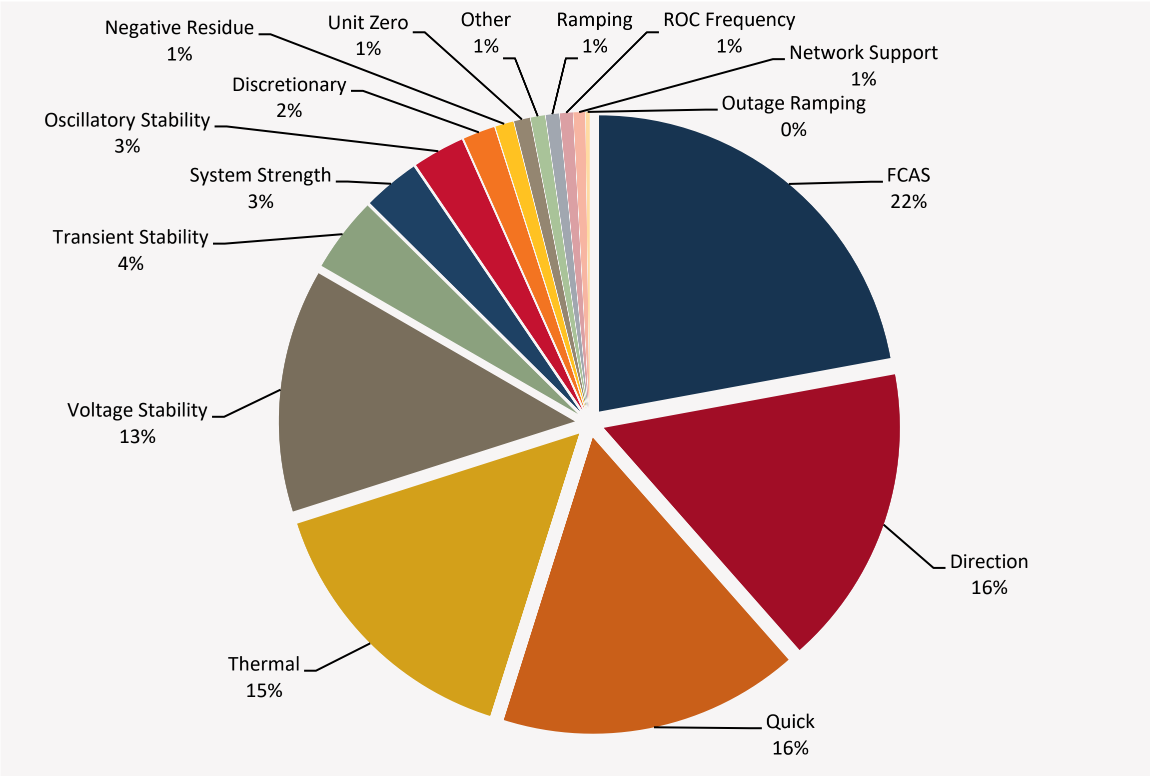
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals for January 2024 that the different types of constraint equations bound.

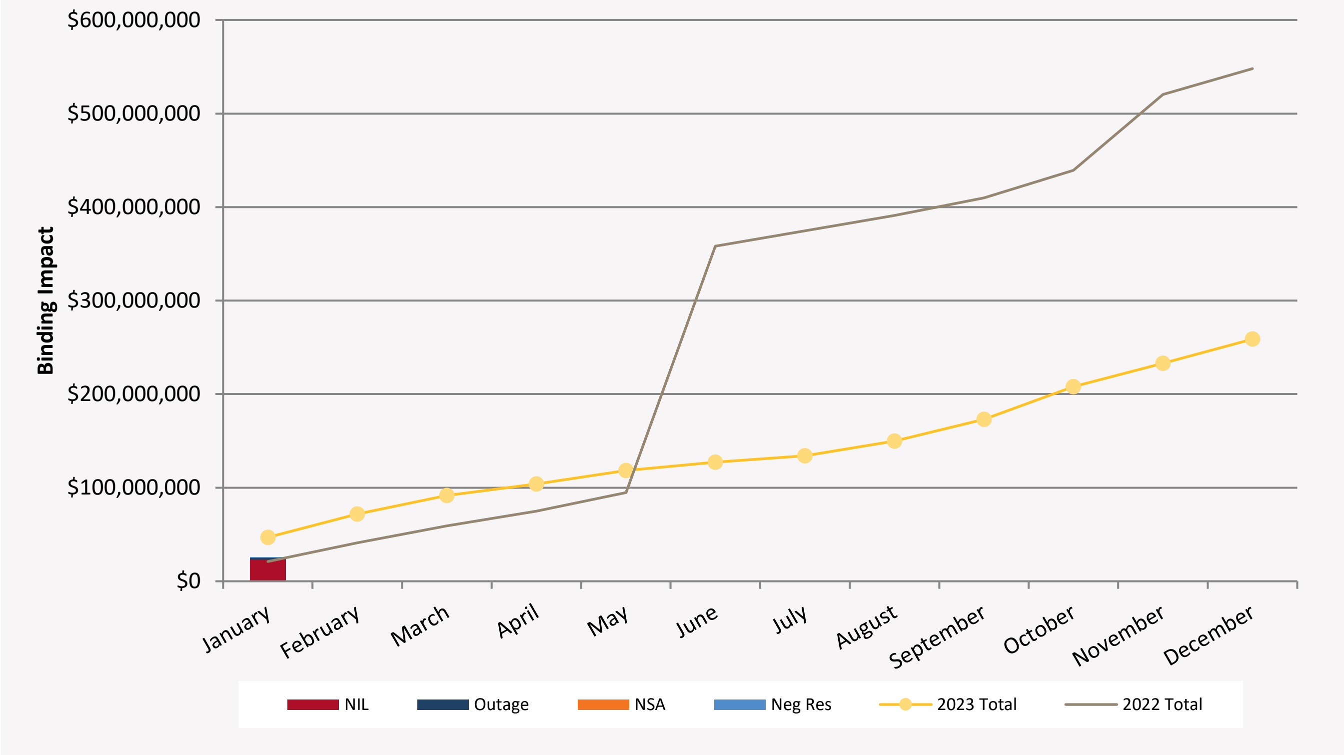
Figure 3 Binding by limit type



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_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	16	6,043% (196.04)	526% (107.)
V::N_HWSM_V2	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 500 kV.	25	524% (305.11)	140.6% (106.11)
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.	102	490% (427.06)	55.75% (114.75)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	197	337% (97.84)	84.19% (33.48)
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	330	193% (60.81)	40.01% (20.86)
V::N_HWSM_SD	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 decelerates. Constraint active for SA flows above 500 MW VIC to SA only, swamped otherwise.	6	156% (126.42)	46.88% (42.68)
V::N_NIL_V1	Out = NIL, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates. Yallourn W G1 on 220kV.	19	153% (318.72)	35.08% (96.82)
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	98	110.06% (261.5)	71.55% (170.67)
NRM_NSW1_VIC1	Negative Residue Management constraint for NSW to VIC flow	49	100.% (9,474)	98.57% (8,959)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N>>NIL_33_34: Investigated and constraint equation was updated on 2/01 to improve PD performance.

V::NIL_NIL_O1: 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.

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

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

N>NIL_969: Investigated and constraint equation was updated on 18/01 to improve PD performance.

N>NIL_997_99A: Investigated and constraint equation was updated on 18/01 to improve PD performance.

V^^SML_NIL_3: 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::N_HWSM_V2: Investigated and no improvement can be made to the constraint equations at this stage.

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

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

V::N_NIL_V1: 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.

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.

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 January 2024.

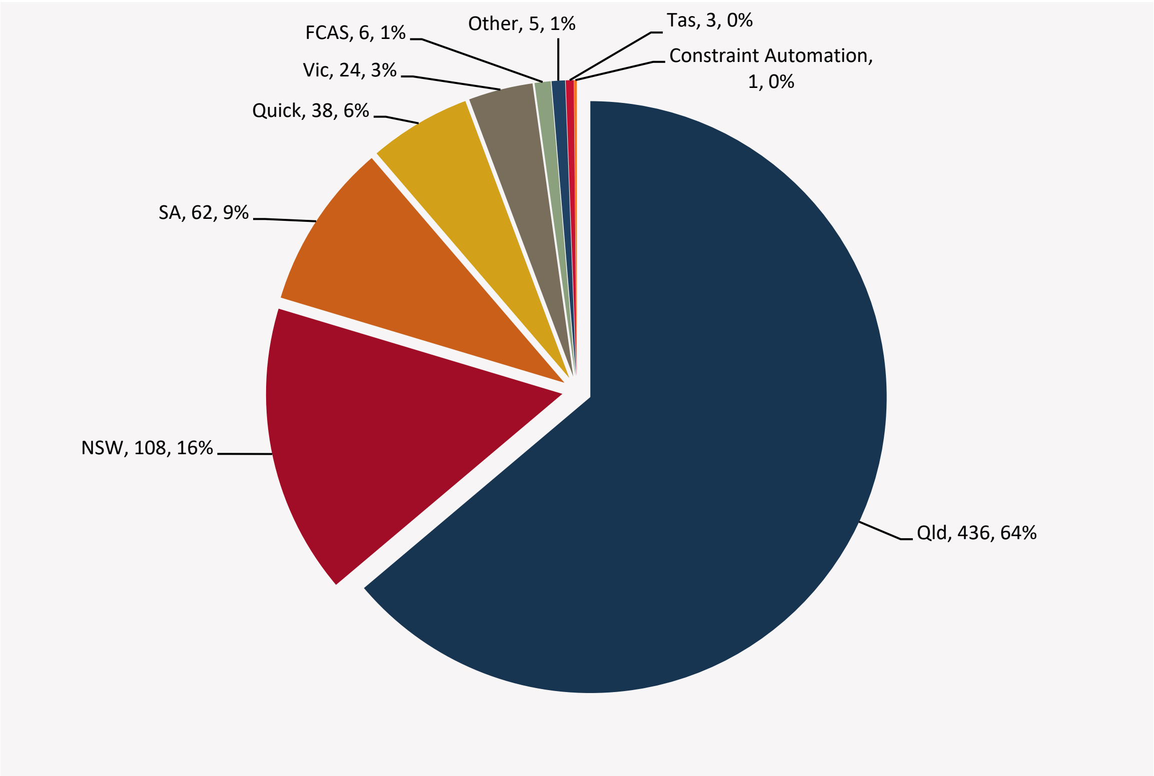
Table 7 Generator and transmission changes

Project	Date	Region	Notes
NIL			

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].

Figure 5 Constraint equation changes



[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

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