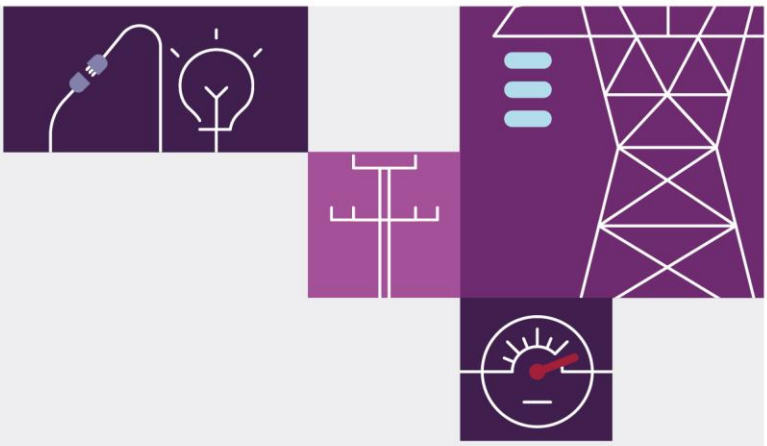
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

November 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 November 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
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	2884 (240.33)	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)	2543 (211.91)	Voltage Stability
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.	2396 (199.66)	Voltage Stability
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2365 (197.08)	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]	2105 (175.41)	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1536 (128.0)	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	1519 (126.58)	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	1396 (116.33)	Thermal
N>NIL_PKTX_LV	Out= Nil, avoid O/L either Parkes 132kV/66kV Transformer on NIL trip, Feedback.	1033 (86.08)	Thermal
N>>NIL_970_051	Out= NIL, avoid O/L BurJK to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	1031 (85.91)	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	3,167,502	Thermal
N>>NIL_970_051	Out= NIL, avoid O/L BurJK to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	2,663,824	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]	2,101,652	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.	1,802,701	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	1,674,470	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	1,247,916	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1,229,689	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	943,283	Thermal
N^^N_NIL_X5_BESH	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of Bendigo to Shepparton 220kV line in NW Victoria	456,578	Voltage Stability
V_ARARATWF_FLT_60	Limit Ararat Wind Farm upper limit to 60 MW to manage post contingent voltage oscillation	397,989	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

[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
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW	11 (0.91)	FCAS
F_T+LREG_0050	Tasmania Lower Regulation Requirement greater than 50 MW	9 (0.75)	FCAS
N_SUNRSF1_0INV	Sunraysia Solar Farm inverter limit of zero. Constraint to violate if Sunraysia Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	8 (0.66)	System Strength
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)	7 (0.58)	Voltage Stability
F_S+NIL_HPR_G+L_LREG	Out= NIL, Hornsdale Battery Joint HPRG1+HPRL1 Energy & FCAS LowerReg ramping constraint	6 (0.5)	FCAS
N>NIL_999	Out= Nil, avoid O/L Bango999 to Cowra (999) on trip of Nil, Feedback	4 (0.33)	Thermal
N_FINLYSF1_0INV	Finley Solar Farm inverter limit of zero. Constraint to violate if Finley Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	4 (0.33)	System Strength
NC_V_GLRWNSF1	Non Conformance Constraint for GLENROWAN WEST SF1	3 (0.25)	Non-Conformance
F_S+NIL_HPR_G+L_RREG	Out= NIL, Hornsdale Battery Joint HPRG1+HPRL1 Energy & FCAS RaiseReg ramping constraint	2 (0.16)	FCAS
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	1 (0.08)	Other

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_T+RREG_0050	Constraint equation violated for 3 non-consecutive DIs on 3/11/2023 1025 hrs, 29/11/2023 1010 hrs, 30/11/2023 0810 hrs and 8 consecutive DIs on 18/11/2023 from 1210 hrs to 1245 with a max violation degree of 50 MW occurring for all DIs with exception to 30/11/2023 0810 hrs. Constraint equation violated due to Tasmania's raise regulation service availability being less than the requirement. In addition, the 8 consecutive violating DIs were caused by SCADA issues.
F_T+LREG_0050	Constraint equation violated for 8 consecutive DIs on 18/11/2023 from 1210 hrs to 1245 hrs, and 1 DI on 29/11/2023 1010 hrs with a max violation degree of 50 MW for all DIs. Constraint equation violated due to Tasmania's lower regulation service availability being less than the requirement. In addition, the 8 consecutive violating DIs were caused by SCADA issues.
N_SUNRSF1_0INV	Constraint equation violated for 2 consecutive DIs on 4/11/2023 from 1905 hrs to 1910 hrs, and 6 consecutive DIs on 5/11/2023 from 1835 hrs to 1900 hrs with a max violation degree of 0.001 MW. Constraint equation violated due to Sunraysia Solar Farm exceeding its inverter limit.
N^N-LS_SVC	Constraint equation violated for 6 consecutive DIs on 13/11/2023 from 0635 hrs to 0700 hrs, and 1 DI on 13/11/2023 1455 hrs with a max violation degree of 28.04 MW occurring on 13/11/2023 0635 hrs. Constraint equation violated due to competing requirements with the import limits on DirectLink set by R029051_002_RAMP_F.

Constraint Equation ID (System Normal Bold)	Description
F_S+NIL_HPR_G+L_LREG	Constraint equation violated for 6 non-consecutive DIs from 30/11/2023 1215 hrs to 30/11/2023 1635 hrs with a max violation degree of 23.2 MW occurring on 30/11/2023 1635 hrs. Constraint equation violated due to Hornsdale Battery lower regulation service availability being less than the requirement.
N>NIL_999	Constraint equation violated for 4 non-consecutive DIs from 11/11/2023 1805 hrs to 21/11/2023 1755 hrs with a max violation degree of 21.61 MW occurring on 21/11/2023 1755 hrs. Constraint equation violated due to 132 kV line Bango999 to Cowra (999) exceeding its limit.
N_FINLYSF1_0INV	Constraint equation violated for 4 consecutive DIs on 5/11/2023 from 1835 hrs to 1850 hrs with a max violation degree of 0.001 MW. Constraint equation violated due to Finley Solar Farm exceeding its inverter limit.
NC_V_GLRWNSF1	Constraint equation violated for 3 non-consecutive DIs on 12/11/2023 at 1120 hrs, 1150 hrs, and 1155 hrs with a max violation degree of 0.02 MW occurring on 12/11/2023 1155 hrs. Constraint equation violated due to non-conformance of Glenrowan Solar Farm.
F_S+NIL_HPR_G+L_RREG	Constraint equation violated for 2 non-consecutive DIs on 30/11/2023 1615 hrs and 30/11/2023 2000 hrs with a max violation degree of 8.1 MW occurring on 30/11/2023 1615 hrs. Constraint equation violated due to Hornsdale Battery raise regulation service availability being less than the requirement.
V_T_NIL_FCSPS	Constraint equation violated for 1 DI on 30/11/2023 0810 hrs with a violation degree of 89.42 MW. Constraint equation violated due to competing requirements with the export limits of Basslink set by TVBL_ROC.

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	2780 (231.67)	165.03 (203.99)
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)	2530 (210.83)	-55.55 (-24.46)
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	1826 (152.17)	-448.69 (-462.01)
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.	1613 (134.42)	146.73 (-61.85)
F_MAIN++LREG_0210	T-V-MNSP1 Import	Mainland Lower Regulation Requirement greater than 210 MW, Basslink able transfer FCAS	1361 (113.42)	-449.03 (-462.01)
N>>NIL_970_051	VIC1-NSW1 Export	Out= NIL, avoid O/L BurJK to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	910 (75.83)	-184.42 (1103.5)
NRM_NSW1_VIC1	VIC1-NSW1 Import	Negative Residue Management constraint for NSW to VIC flow	798 (66.5)	-140.81 (-1340.97)
N>>NIL_964_84_S	NSW1-QLD1 Import	Out= NIL, avoid O/L Port Macquarie to Herron Creek Tee (964/2) on trip of Tamworth to Liddell (84) line, Feedback	789 (65.75)	-686.28 (-1224.32)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N>>NIL_964_84_S	N-Q-MNSP1 Import	Out= NIL, avoid O/L Port Macquarie to Herron Creek Tee (964/2) on trip of Tamworth to Liddell (84) line, Feedback	784 (65.33)	-19.0 (-164.83)
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 75 MW	724 (60.33)	-457.28 (-462.0)

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

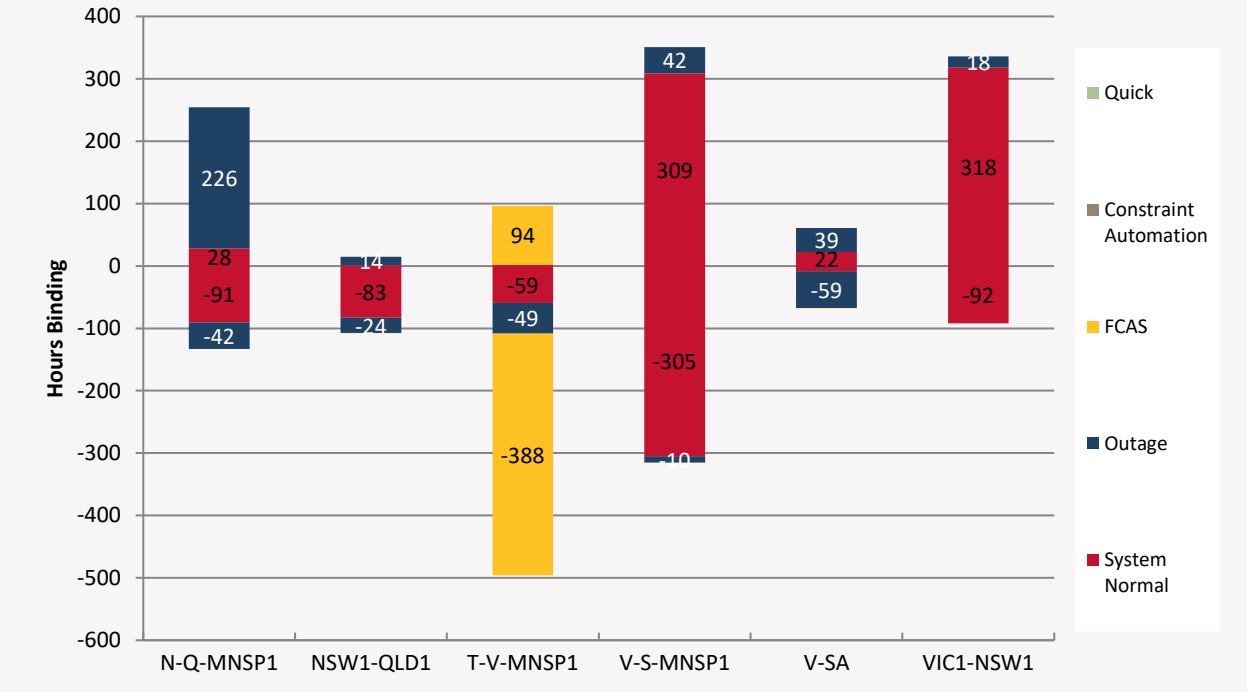
Non-real time constraint automation was not used.

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.

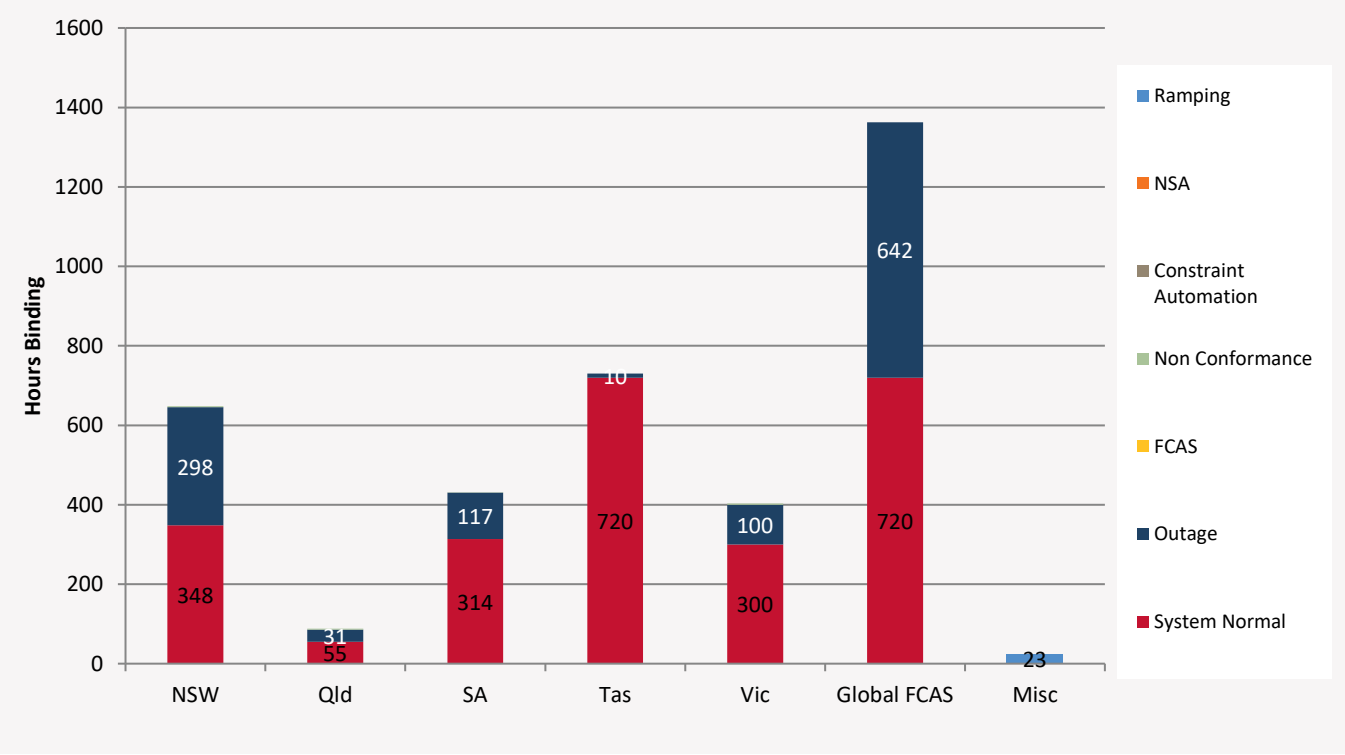
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

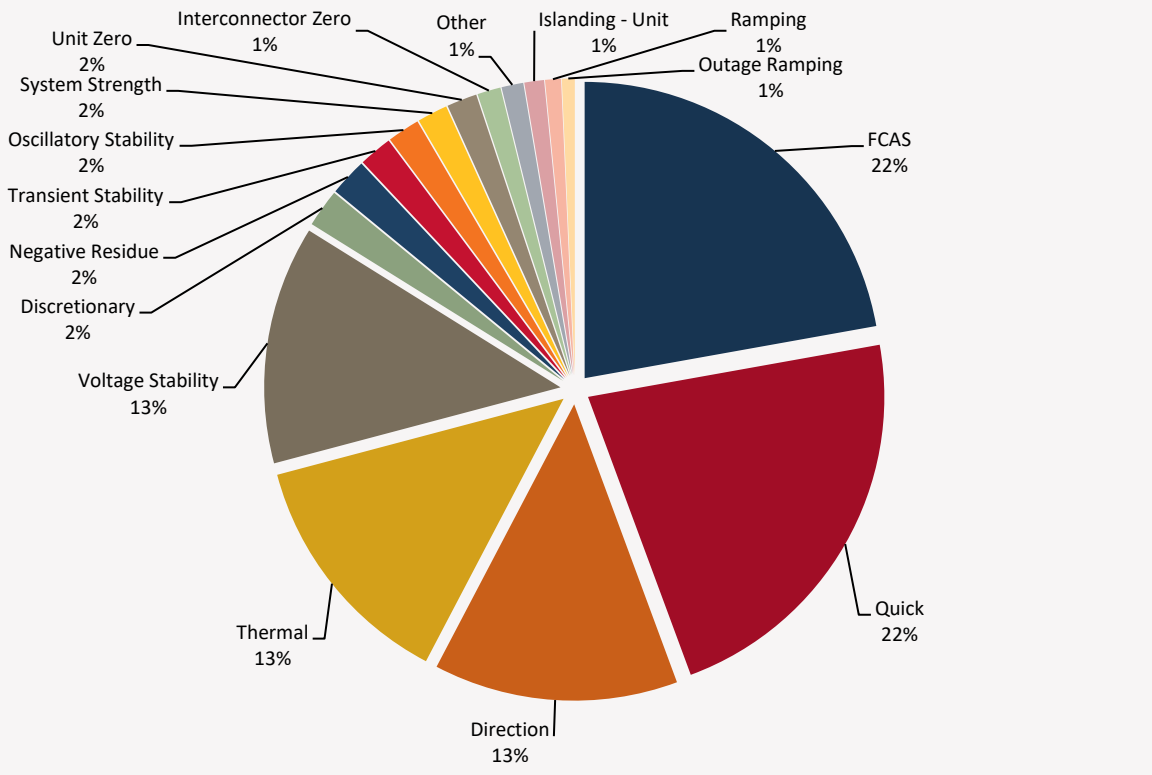
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

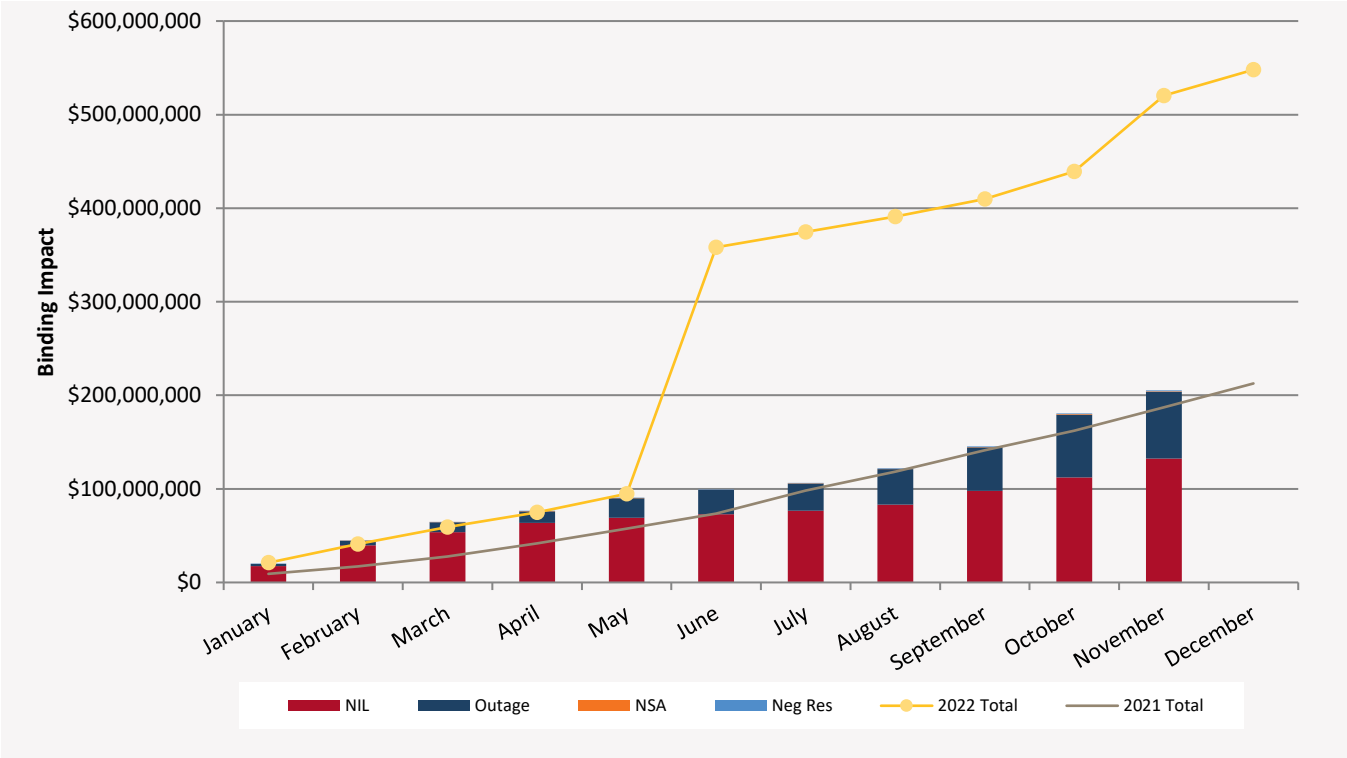
Figure 3 Binding by limit type



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
S^^V_SETB_1	Out= one South East to Tailem Bend 275kV line, voltage collapse equation Tailem Bend-Keith #2 132kV Line <=135 MW on trip of other Tailem Bend-South East 275kV line, Feedback (Note: with both SE series caps I/S or O/S)	4	3,182% (20.16)	1,228% (10.23)
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	3	523% (31.04)	255% (19.24)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	13	465% (40.8)	136.71% (16.1)
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)	240	328% (97.09)	68.85% (26.69)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	3	215% (40.8)	134.38% (27.3)
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.	6	109.01% (190.76)	40.61% (80.17)
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	166	101.4% (82.27)	32.72% (27.55)
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	5	100.01% (235.62)	68.35% (178.17)
N>N-BAMB_132_OPEN_A	Out = Any one 132 kV line between Ballina and Mullumbimby that opens the 132 kV path, avoid Lismore132 to Dunoon 132kV line (9U6 or 9U7) O/L on trip of the other 9U7 or 9U6 line, Swamp out when all 3 directlink cable O/S, feedback	6	86.33% (62.61)	80.54% (54.48)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

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

S^^V_SETB_1: Investigated and no improvement can be made to the constraint equation at this stage.

N>NIL_999: 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_998: Investigated and no improvement can be made to the constraint equation at this stage.

N>NIL_969: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_NIL_O2: 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^N-LS_SVC: Investigated and constraint equation was updated on 27/08 to improve PD performance.

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

NRM_NSW1_VIC1: 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 November 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Ross – Woree No. 8905 275 kV Line	1 November 2023	QLD	Line Commissioned
Chinchilla Bess (Gen Component)	21 November 2023	QLD	New Battery
Chinchilla Bess (Load Component)	21 November 2023	QLD	New Battery
Glenrowan Solar Farm	21 November 2023	Victoria	New Generator
Goyder South Wind Farm 1b	21 November 2023	SA	New Generator
Broken Hill Battery 50 MW (Load Mode)	28 November 2023	NSW	New Battery
Broken Hill Battery 50 MW (Gen Mode)	28 November 2023	NSW	New Battery

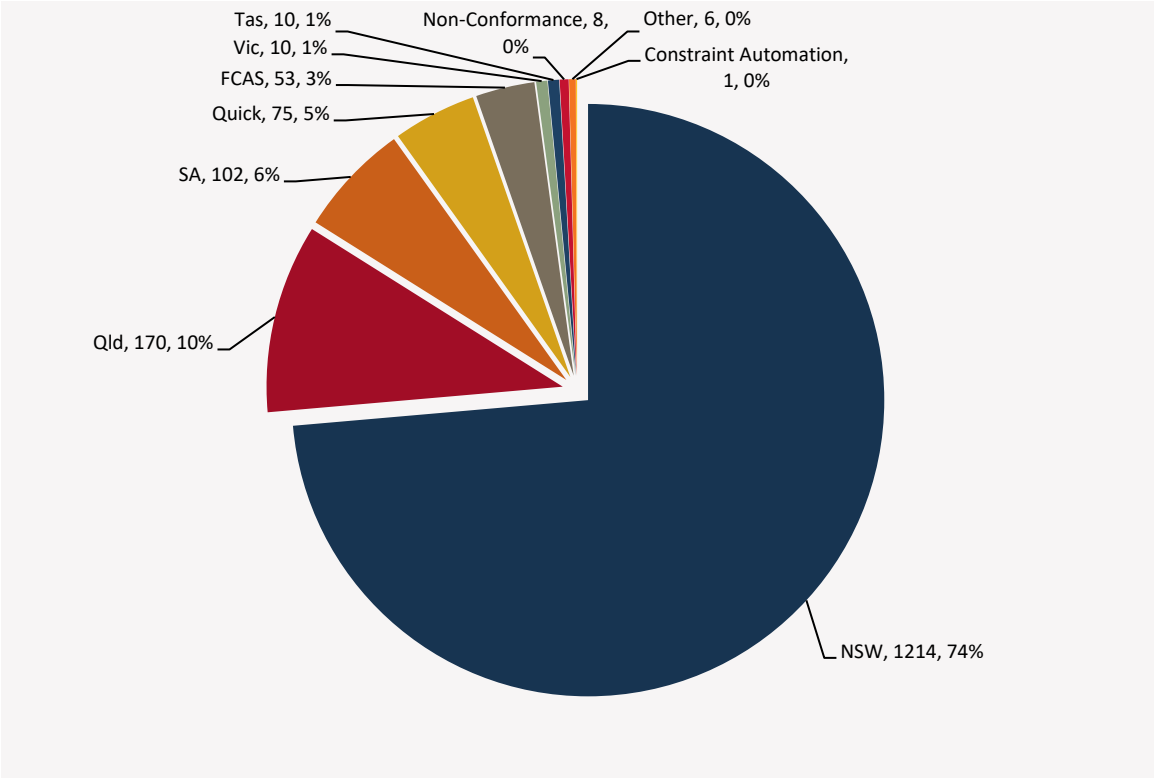
3.1 Constraint Equation Changes

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