Monthly Constraint Report

April 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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1 Introduction

This report details constraint equation performance and transmission congestion related issues for April 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
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	5383 (448.58)	Interconnector Zero
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1970 (164.16)	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]	1644 (137.0)	Thermal
V^^V_MLNK_KGTS	Out= Murraylink, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line	1516 (126.33)	Voltage Stability
N>NIL_9R6_9R5	Out= Nil, avoid O/L Wagga North to Wagga132 (9R6) on trip of Wagga North to Wagga330 (9R5) line, Feedback	1100 (91.66)	Thermal
N^^V_MLNK_1	Out = Murraylink, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	836 (69.66)	Voltage Stability
N>>NIL_964_84_S	Out= NIL, avoid O/L Port Macquarie to Herron Creek Tee (964/2) on trip of Tamworth to Liddell (84) line, Feedback	834 (69.5)	Thermal
N>N_LSDU_9U6_1	Out= one of Lismore 132 to Dunoon 132kV line (9U6 or 9U7), avoid O/L the remaining 132kV line, NSW to Qld limit	760 (63.33)	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	732 (61.0)	Thermal
Q_STR_7C0K_HASF_2	No limit to Haughton Solar Farm if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7, NQLD>250&270(AVG),Ross_FN>100&120(AVG), Haughton Syncon is ON, Zero otherwise.	593 (49.41)	System Strength

2.2 Top 10 binding impact constraint equations

Binding constraint equations affect electricity market pricing. The binding impact is used to distinguish the severity of different binding constraint equations.

The binding impact of a constraint is derived by summarising the marginal value for each dispatch interval (DI) from the marginal constraint cost (MCC) re-run[1] over the period considered. The marginal value is a mathematical term for the binding impact arising from relaxing the RHS of a binding constraint by one MW. As the market clears each DI, the binding impact is measured in $/MW/DI.

The binding impact in $/MW/DI is a relative comparison and a helpful way to analyse congestion issues. It can be converted to $/MWh by dividing the binding impact by 12 (as there are 12 DIs per hour). This value of congestion is still only a proxy (and always an upper bound) of the value per MW of congestion over the period calculated; any change to the limits (RHS) may cause other constraints to bind almost immediately after.

Table 2 Top 10 binding impact network constraint equations

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Limit Type
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2,730,904	Thermal
V^^V_MLNK_KGTS	Out= Murraylink, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line	1,695,624	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 [Note: swamped with 96M or 9UJ or 9UH is O/S]	1,603,924	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	820,609	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	697,786	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	617,389	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	276,021	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge (733/1 and 734/1), Feedback	265,013	Thermal
N>NIL_901	Out= Nil, avoid O/L West Wyalong to Temora 132kV (901) line on trip of Nil, Feedback	258,885	Thermal
S>NIL_HUWT_STBG3	Out = Nil; Limit Snowtown WF generation to avoid Snowtown - Bungama line OL on loss of Hummocks - Waterloo line. [Note: Constraint Swamped when Wattle PT when generating >=60 MW)	247,370	Thermal

[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>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	8 (0.66)	Thermal
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW	6 (0.5)	FCAS
F_T+LREG_0050	Tasmania Lower Regulation Requirement greater than 50 MW	4 (0.33)	FCAS
N>NIL_9R5_9R6_N	Out= NIL, avoid O/L Wagga330 to Wagga North (9R5) 132kV line on trip of Wagga132 to Wagga North (9R6) 132kV line, Feedback	2 (0.16)	Thermal
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event, Basslink unable to transfer FCAS	1 (0.08)	FCAS
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	1 (0.08)	FCAS
N>NIL_9R6_9R5_N	Out= NIL, avoid O/L Wagga132 to Wagga North (9R6) 132kV line on trip of Wagga330 to Wagga North (9R5) 132kV line, Feedback	1 (0.08)	Thermal
S_WATERLWF_RB	Out= Nil, Limit Waterloo WF output to its runback MW capability, DS only	1 (0.08)	Discretionary

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	Constraint equation violated for 2 consecutive DIs between 29/04/2024 1725 hrs and 29/04/2024 1730 hrs, 1 DI on 29/04/2024 1740 hrs and 5 consecutive DIs between 29/04/2024 1750 hrs and 29/04/2024 1810 hrs. The constraint equation had a max violation degree of 12.27 MW on 29/04/2024 1755 hrs. Constraint equation violated due to ramp rate and minimum technical operating limits of Uranquinty Units 1, 2, 3 and 4.
F_T+RREG_0050	Constraint equation violated for 5 non-consecutive DIs between 03/04/2024 1140 hrs and 03/04/2024 1550 hrs and 1 DI on 18/04/2024 1005 hrs. The constraint equation had a max violation degree of 47.64 MW on 18/04/2024 1005 hrs. Constraint equation violated due to the Tasmania raise regulation service availability being less than the requirement.
F_T+LREG_0050	Constraint equation violated for 4 non-consecutive DI's between 03/04/2024 1155 hrs and 07/04/2024 0445 hrs with a max violation degree of 6.72 MW at 03/04/2024 1155 hrs, 1205 hrs and 1315 hrs. Constraint equation violated due to the Tasmania lower regulation service availability being less than the requirement.
N>NIL_9R5_9R6_N	Constraint equation violated for 2 non-consecutive DIs on 23/04/2024 1750 hrs and 29/04/2024 1725 hrs with a max violation degree of 3.01 MW on 29/04/2024 1725 hrs. Constraint equation violated due to ramp rate limit of Uranquinty Units 1, 2, 3 and 4.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 1 DI on 24/04/2024 1705 hrs with a violation degree of 14 MW. Constraint equation violated due to Tasmanian raise 6 second service availability being less than required.
F_T_AUFLS2_R6	Constraint equation violated for 1 DI on 24/04/2024 1705 hrs with a violation degree of 5.39 MW. Constraint equation violated due to Tasmanian raise 6 second service availability being less than required.
N>NIL_9R6_9R5_N	Constraint equation violated for 1 DI on 29/04/2024 1725 hrs with a violation degree of 0.75 MW. Constraint equation violated due to ramp rate limit of Uranquinty Units 1, 2, 3 and 4.
S_WATERLWF_RB	Constraint equation violated for 1 DI on 19/04/2024 0830 hrs with a violation degree of 0.54 MW. Constraint equation violated due to Waterloo Wind Farm runback capability being less than 0 MW.

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	4789 (399.08)	0.0 (0.0)
N^^V_MLNK_1	VIC1-NSW1 Import	Out = Murraylink, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	836 (69.67)	-389.83 (-845.9)
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	813 (67.75)	-844.7 (-1159.17)
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	797 (66.42)	50.29 (-81.0)
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	759 (63.25)	-384.92 (-441.0)
N>N_LSDU_9U6_1	N-Q-MNSP1 Export	Out= one of Lismore 132 to Dunoon 132kV line (9U6 or 9U7), avoid O/L the remaining 132kV line, NSW to Qld limit	759 (63.25)	38.55 (96.04)
F_T++NIL_ML_L6	T-V-MNSP1 Export	Out = Nil, Lower 6 sec requirement for a Tasmania Load Event, Basslink able to transfer FCAS	697 (58.08)	248.15 (439.0)
V^^V_MLNK_KGTS	V-S-MNSP1 Import	Out= Murraylink, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line	577 (48.08)	0.0 (0.0)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	550 (45.83)	178.56 (439.0)
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 200 MW	513 (42.75)	-428.65 (-441.0)

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.

Table 6 Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_BRIS_55306556	16/04/2024 11:55 to 16/04/2024 15:00	CA_BRIS_55306556 was built to manage the overloading of Tailem Bend 132/275 kV No. 4 transformer for the trip of Tungkillo – Tailem Bend 275 kV Line 2.
CA_SYDS_552B00F8	12/04/2024 09:45 to 12/04/2024 10:55	CA_SYDS_552B00F8 was built to manage the overloading of 9R5 Line for the trip of 99M line.

2.5.1 Further Investigation

CA_BRIS_55306556: Constraint automation was invoked and intermittently binding. CA_BRIS_55306556 was built due to a Real Time Contingency Analysis thermal violation of Tailem Bend 132/275 kV No. 4 transformer during the outage of Tungkillo – Tailem Bend 275 kV Line 1. Constraint automation equation removed the thermal violation and reduced MW export from South Australia to Victoria through the Heywood Interconnector. The constraint was revoked at 16/04/2024 1500 hrs once constraint equation S>>TBTU_TUTB_TBT4 was built to manage future violation issues.

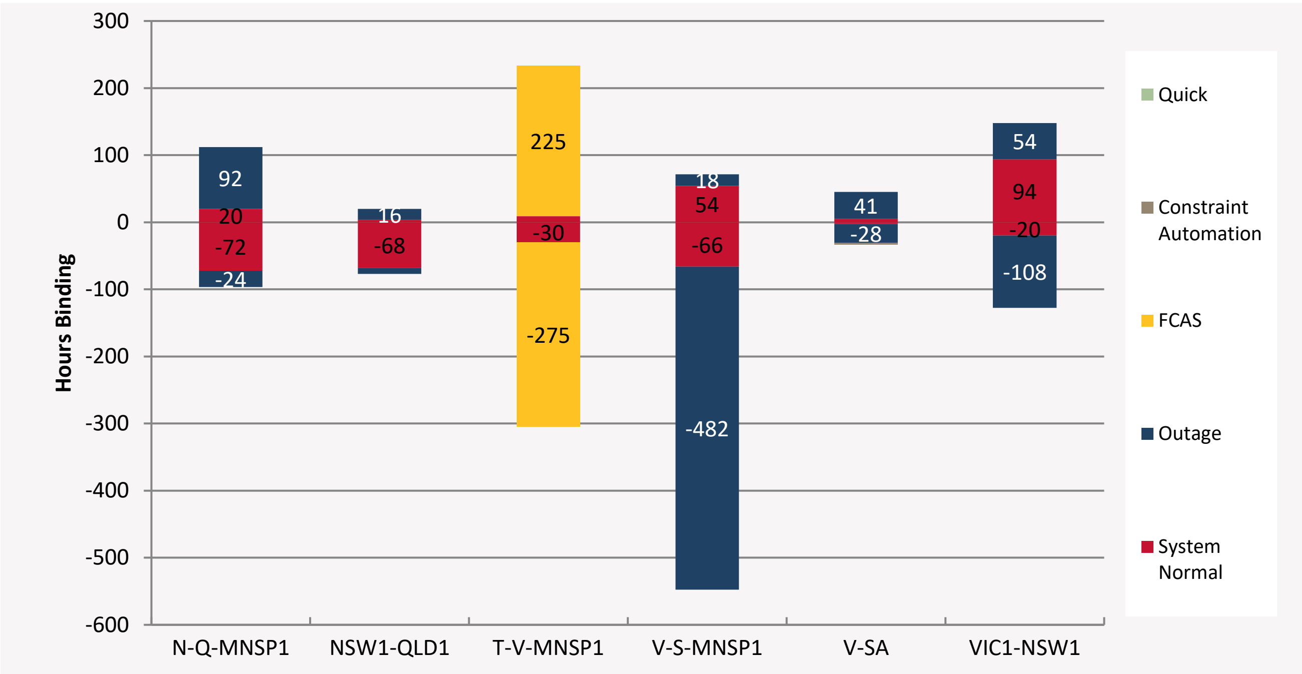
CA_SYDS_552B00F8: Constraint automation equation was invoked and binding until 12/04/2024 1030 hrs when N>NIL_9R5, which manages the overloading of 9R5 Line for NIL trip, started to bind. CA_SYDS_552B00F8 was built due to an observed Real Time Contingency Analysis thermal violation. 9R6 Line returned to service at 12/04/2024 1035 hrs which reduced flow on 9R5 such that neither CA_SYDS_552B00F8 or N>NIL_9R5 was binding. The constraint automation equation reduced flow on line 9R5 and removed the thermal violation. CA_SYDS_552B00F8 was revoked at 12/04/2024 1055 hrs. Constraint equation N>9R6_9R5_991 was built to manage future violation issues.

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.

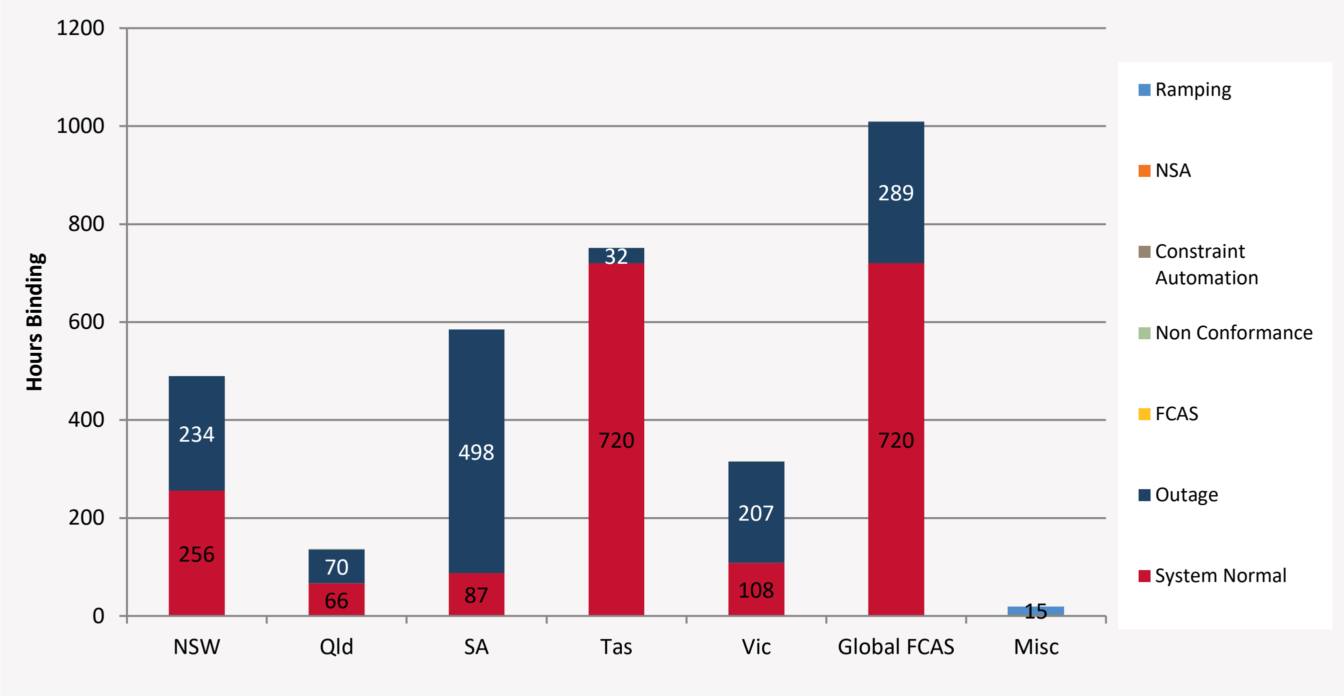
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

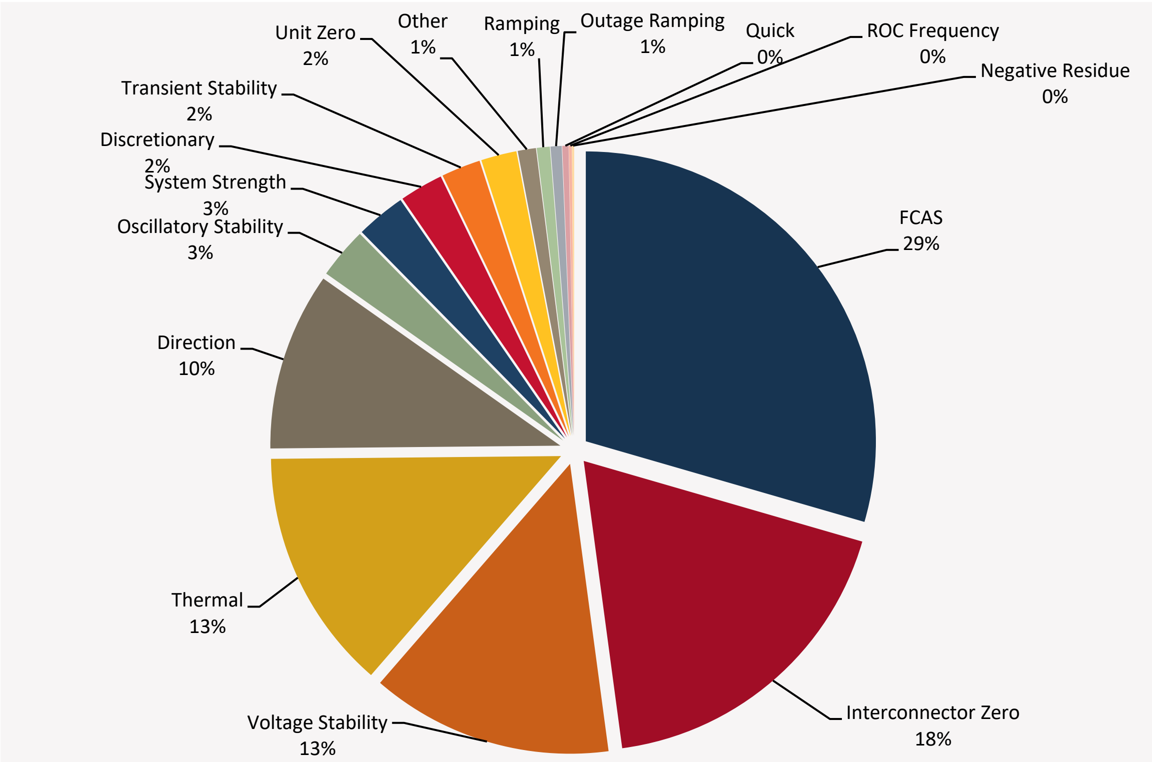
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

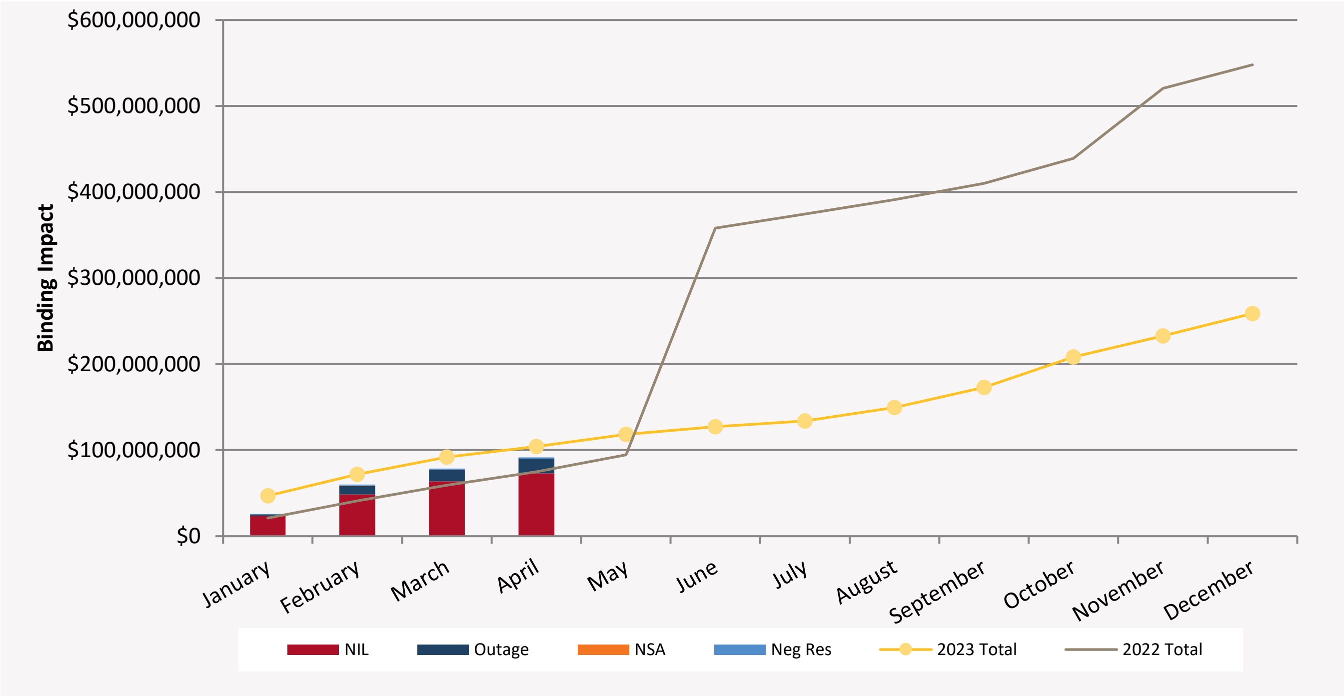
Figure 3 Binding by limit type



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 0.

Table 7 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	37	1,894% (9,498)	621% (3,600)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	43	1,101% (469.94)	63.9% (133.16)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	14	870% (10.1)	359% (8.31)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	5	860% (10.1)	316% (8.6)
N_X_MBTE2_A	Out= two Directlink cables, NSW to Qld limit	63	199% (30.1)	15.69% (6.96)
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.	260	150% (363.82)	45.7% (161.56)
N>N_LSDU_9U6_1	Out= one of Lismore 132 to Dunoon 132kV line (9U6 or 9U7), avoid O/L the remaining 132kV line, NSW to Qld limit	201	129.78% (74.28)	51.46% (29.19)
N^^V_MLNK_1	Out = Murraylink, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	169	114.74% (338.35)	27.68% (118.07)
NRM_NSW1_VIC1	Negative Residue Management constraint for NSW to VIC flow	5	100.% (9,479)	99.99% (9,310)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N>N_LSDU_9U6_1: Investigated and no improvement can be made to the constraint equation at this stage.

N^^V_MLNK_1: 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. Changes to the status of the reactive devices between DS/PD contributes to the PD accuracy.

V_T_NIL_FCSPS: This constraint equation uses analog values for the load enabled for the FCSPS in Pre-dispatch. This value can change quickly in dispatch, and this is not possible to predict in Pre-dispatch. No changes proposed.

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.

N_X_MBTE2_A: 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.

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

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

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 April 2024.

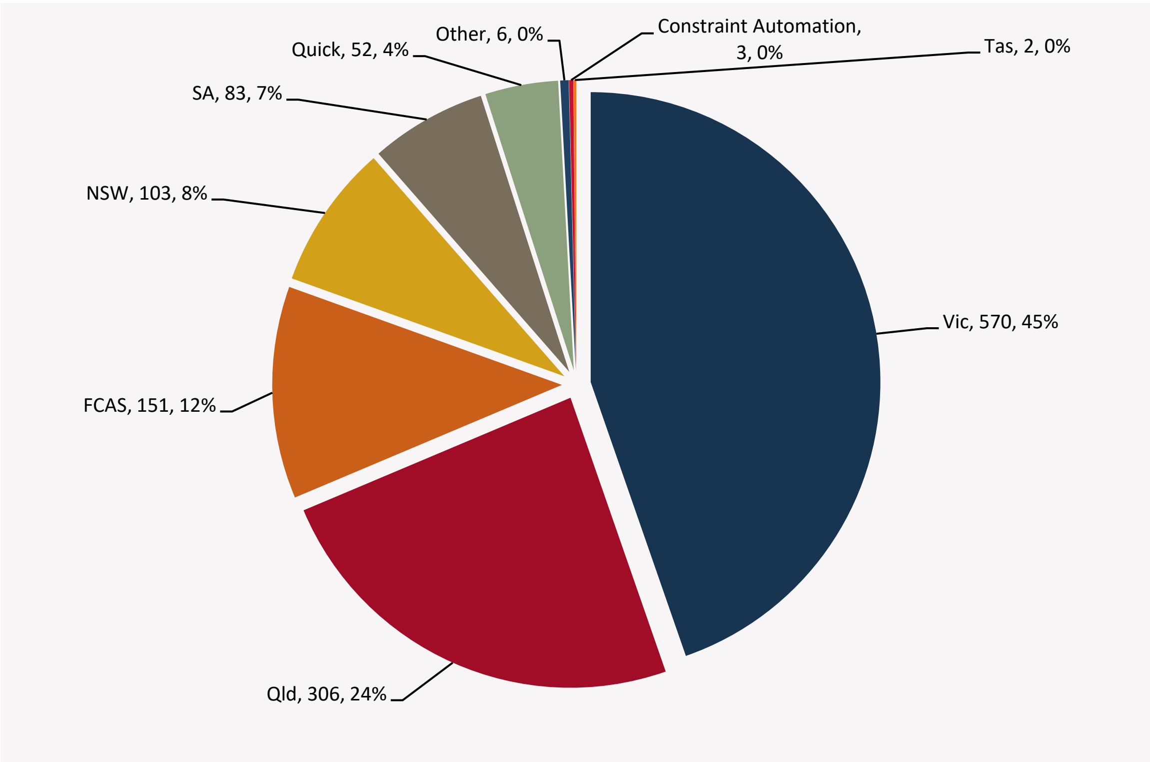
Table 8 Generator and transmission changes

Project	Date	Region	Notes
H93 Guybal Munjan 275 kV cut-in	04/04/2024 1435 hrs	QLD	H93 Guybal Munjan 275 kV Switching Station and H13 Ross – H93 Guybal Munjan No.8916 295 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].

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