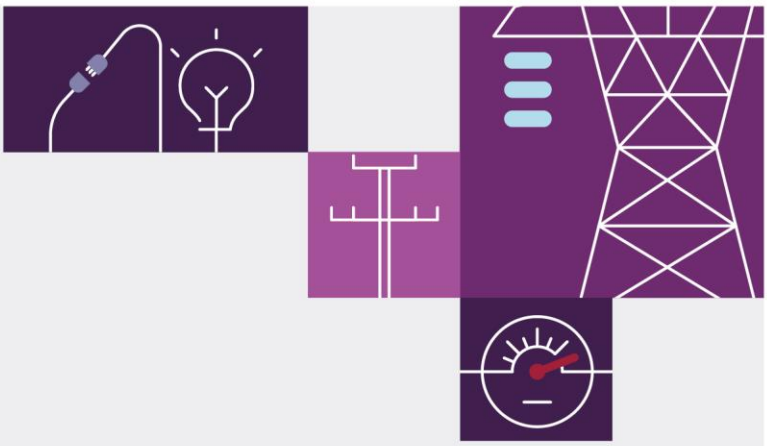
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

May 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 May 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
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.	3714 (309.5)	System Strength
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)	3123 (260.25)	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	1642 (136.83)	Thermal
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	1513 (126.08)	Interconnector Zero
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1297 (108.08)	Thermal
S_ISLE_CRK_10	Discretionary upper limit on Cathedral Rocks windfarm<=10 MW when 2-4 syn cons I/S for SA is at risk of islanding or in islanded mode(Note: this equation is swamped when 0-1 sync cons are I/S)	1214 (101.16)	Discretionary
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	1178 (98.16)	Voltage Stability
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1052 (87.66)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	992 (82.66)	Thermal
V_MURRAWRWF_FLT_90	Limit Murra Warra Wind Farm 1+2 upper limit to 90 MW to manage system stability on the next contingency due to voltage oscillation	990 (82.5)	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_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1,314,664	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1,129,967	Thermal
V_MURRAWRWF_FLT_90	Limit Murra Warra Wind Farm 1+2 upper limit to 90 MW to manage system stability on the next contingency due to voltage oscillation	1,041,594	System Strength
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	628,981	Thermal
V_ARARATWF_FLT_0	Limit Ararat Wind Farm upper limit to 0 MW to manage post contingent voltage oscillation	607,008	System Strength
V_KIAMSF_FLT_50	Limit Kiamal solar farm upper limit to 50 MW to manage post contingent voltage oscillation	552,653	System Strength
N::N_DTKV_2	Out = Dapto - Kangaroo Valley (18) 330kV line, transient stability limit (Snowy-NSW) for loss of one 330kV line between Yass and Bannaby/Marulan with summated flow on 4+5+61 <=1500	436,142	Transient Stability
S_ISLE_CANUNDA_35	Discretionary upper limit on Canunda windfarm<=35MW & No. in-service wind turbines for canunda at 23 Turbines.(Note otherwise,Canunda will be constrained to 0 MW)	390,755	Discretionary
Q_STR_7C8C_KBWF	Limit Kaban Wind Farm output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	382,894	System Strength
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	367,202	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_TARALGA1_2WT	Constraint to violate if Taralga WF wind turbines ONLINE greater than 2. Dispatch only. swamped out otherwise. DS only.	12 (1.0)	System Strength
N_COLMBSF_60_INV	Limit Coleambally Solar Farm upper limit to 0 MW if number of inverter available exceed 60. Dispatch only. swamped out if Inverters are within the limit.	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	7 (0.58)	Network Support
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	6 (0.5)	Negative Residue
N_GOONSF_11_INV	Limit Goonumbla Solar Farm upper limit to 0 MW if number of inverter available exceed 11. Dispatch only. swamped out if Inverters are within the limit.	6 (0.5)	System Strength
Q-SMSF_MVAR	Constraint to violate if Reactive power output of Sun Metals Solar farm is greater than +/10Mvar when it is limited at 0MW output, Swamp if MW >0 (DS only)	5 (0.41)	Unit Zero
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)	4 (0.33)	Voltage Stability
N_BROKENH1_0INV	Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	4 (0.33)	System Strength
N_WSTWYSF1_0INV	Constraint to violate if West Wyalong Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	4 (0.33)	System Strength
Q-RRSF_MVAR	Constraint to violate if Reactive power output of Ross River Solar farm is greater than +/10Mvar when it is limited at 0MW output, Swamp if MW >0 (DS only)	4 (0.33)	Unit Zero

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
N_TARALGA1_2WT	Constraint equation violated for 12 non-consecutive DIs on 30/05/2023 from 0705 hrs to 1605 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Taralga Wind Farm turbine availability greater than 2.
N_COLMBSF_60_INV	Constraint equation violated for 11 consecutive DIs on 03/05/2023 from 0730 hrs to 0820 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Coleambally Solar Farm exceeding its inverter limit.
NSA_Q_BARCALDN	Constraint equation violated for 7 non-consecutive DIs on 03/05/2023 from 0820 hrs to 1550 hrs with a max violation degree of 17.79 MW occurring on 03/05/2023 at 0825 hrs. Constraint equation violated due to Barcaldine GT unit being limited by its start-up profile.
NRM_QLD1_NSW1	Constraint equation violated for 6 non-consecutive DIs on 01/05/2023 from 0040 hrs to 0540 hrs with a max violation degree of 120.48 MW occurring on 01/05/2023 at 0040 hrs. Constraint violated due to competing requirements with the export limits of QNI and Terranora interconnector which were set by constraint equations N>>NIL_33_34 and N^N-LS_SVC, respectively.
N_GOONSF_11_INV	Constraint equation violated for 6 consecutive DIs on 05/05/2023 from 0600 hrs to 0625 hrs with a violation degree of 0.001 MW. Constraint violated due to Goonumbla Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
Q-SMSF_MVAR	Constraint equation violated for 5 consecutive DIs on 02/05/2023 from 1505 hrs to 1525 hrs with a violation degree of 0.001 MW. Constraint violated due to Sun Metals Solar Farm exceeding its MVAr limit.
N^N-LS_SVC	Constraint equation violated for 4 non-consecutive DIs between 16/05/2023 0910 hrs and 25/05/2023 1225 hrs with a max violation degree of 11.45 MW occurring on16/05/2023 at 0910 hrs. Constraint violated due to competing requirement with the import limit of Terranora interconnector which was set by constraint equation QNTE_ROC.
N_BROKENH1_0INV	Constraint equation violated for 4 non-consecutive DIs between 01/05/2023 0535 hrs and 19/05/2023 1145 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Broken Hill Solar Farm exceeding its inverter limit.
N_WSTWYSF1_0INV	Constraint equation violated for 4 non-consecutive DIs on 19/05/2023 from 1145 hrs to 1245 hrs with a violation degree of 0.001 MW. Constraint equation violated due to West Wyalong Solar Farm exceeding its inverter limit.
Q-RRSF_MVAR	Constraint equation violated for 4 consecutive DIs on 02/05/2023 from 1455 hrs to 1510 hrs with a violation degree of 0.001 MW. Constraint violated due to Ross River Solar Farm exceeding its MVAr 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)	3085 (257.08)	-59.5 (-29.0)
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	1588 (132.33)	-24.53 (-173.18)
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	1527 (127.25)	-908.25 (-1199.38)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1384 (115.33)	286.78 (447.0)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	1351 (112.58)	0.0 (0.0)
V^SML_BUDP_3	V-S-MNSP1 Export	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	1175 (97.92)	-3.44 (117.49)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1030 (85.83)	318.37 (447.0)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	720 (60.0)	218.78 (447.01)
F_MAIN++APD_TL_L5	T-V-MNSP1 Import	Out = Nil, Lower 5 min Service Requirement for a Mainland Network Event-loss of APD potlines due to undervoltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS	701 (58.42)	-290.87 (-447.01)

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	695 (57.92)	164.39 (182.44)

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

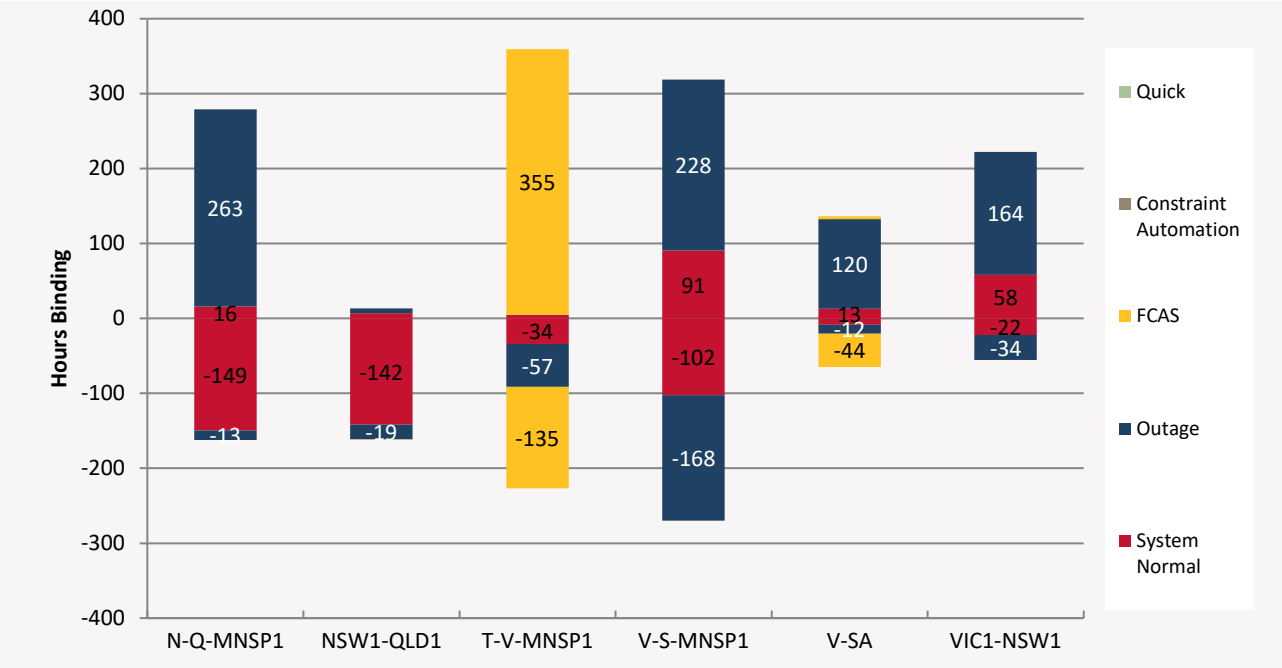
Non-real time constraint automation was not used.

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.

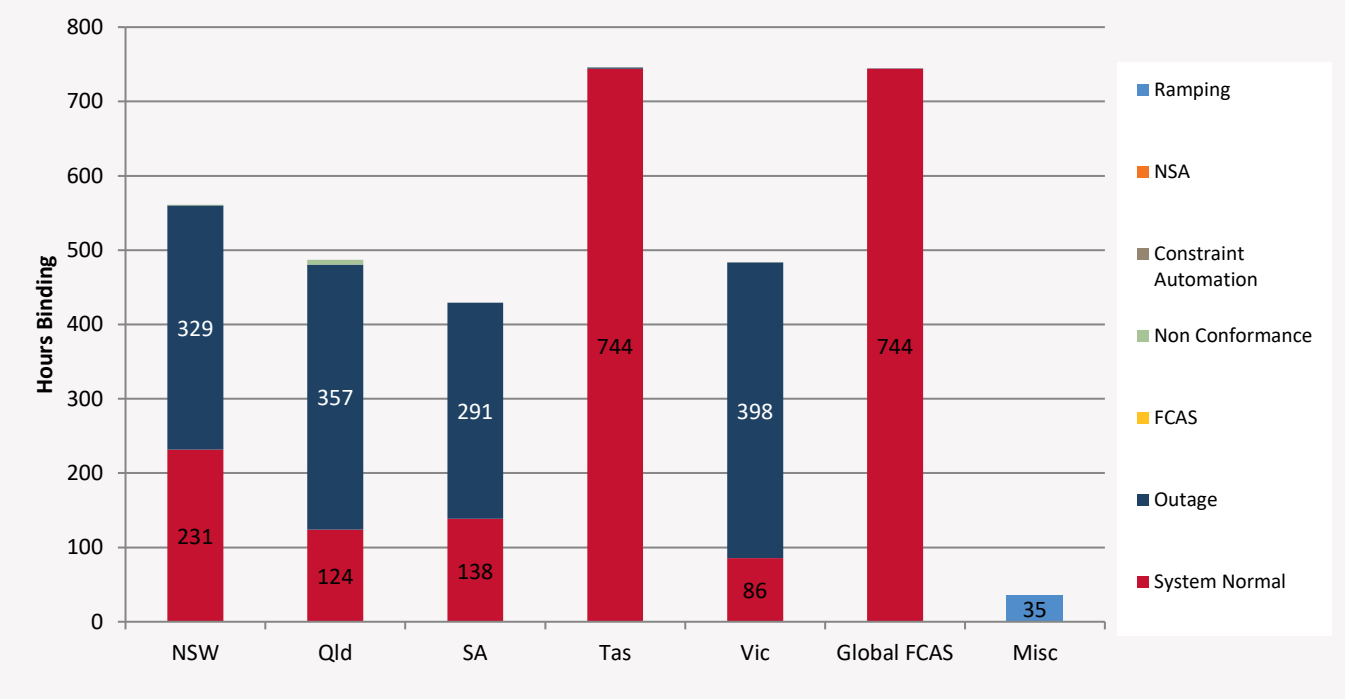
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

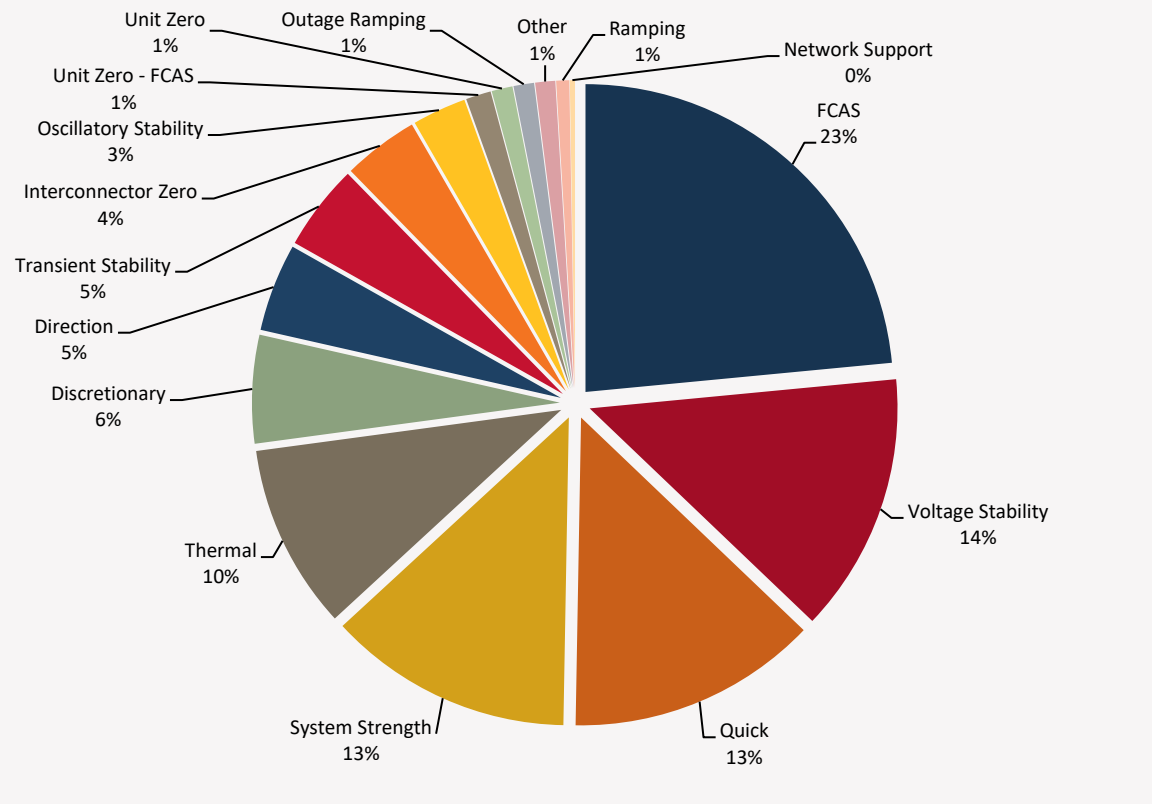
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

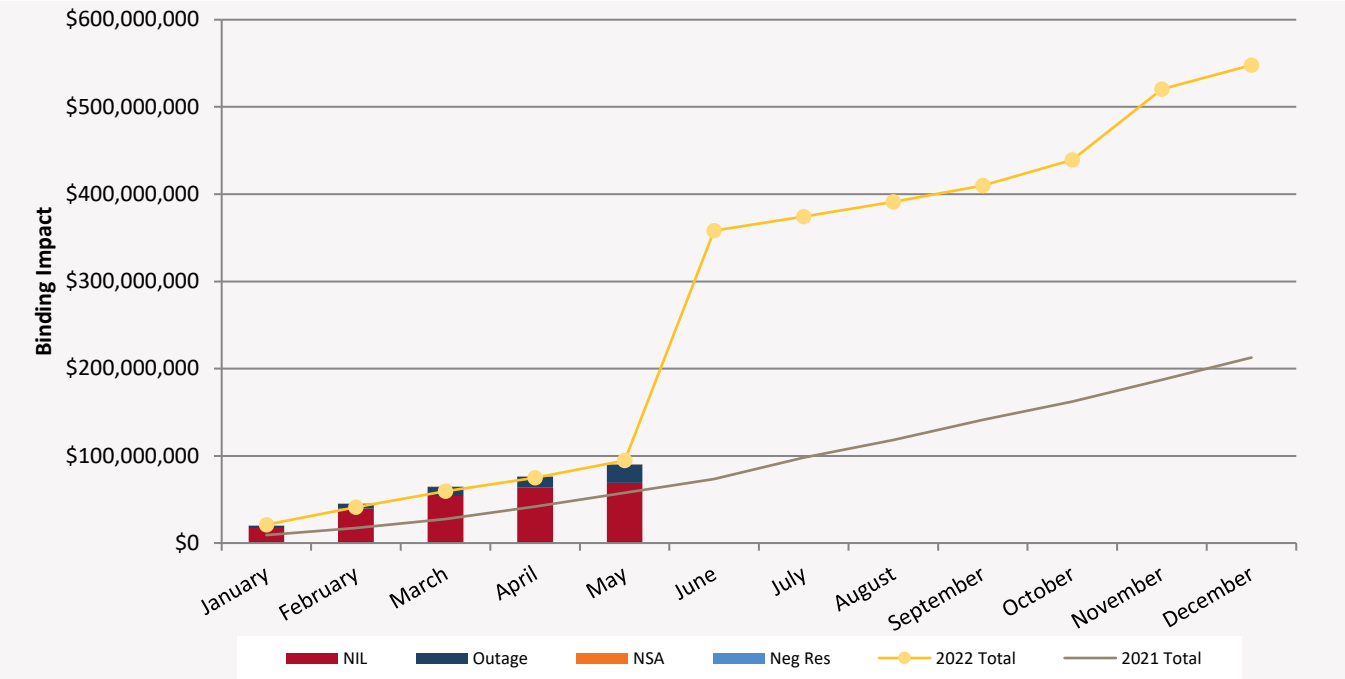
Figure 3 Binding by limit type



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
V::N_JNWG_S2	Out = Jindera to Wagga 330kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	41	31,511% (298.56)	959% (128.15)
V::N_HYSE_V2	Out = Heywood to South East 275kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	93	25,995% (309.88)	505% (126.06)
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	219	14,523% (108.6)	399% (23.45)
Q_STR_7C8C_KBWF	Limit Kaban Wind Farm output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	56	7,961% (119.5)	3,308% (95.74)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_MLMO_V2	Out = Moorabool to Mortlake 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	6	2,876% (434.21)	828% (164.44)
V::N_JNWG_V2	Out = Jindera to Wagga 330kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	23	593% (237.12)	102.88% (118.16)
V::N_MLTX_V1	Out = Moorabool Transformer 500/200kV, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	21	518% (414.61)	112.09% (119.62)
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)	379	349% (101.15)	49.43% (25.49)
N^^V_JNWG_63_X5_1	Out = Jindera to Wagga(62) 330kV line, 63 + X5 open, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	11	321% (393.45)	108.19% (221.08)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_JNWG_S2: Investigated and no improvement can be made to the constraint equation at this stage.

Q_STR_7C8C_KBWF: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_JNWG_V2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_HYSE_V2: Investigated and no improvement can be made to the constraint equation at this stage.

V^SML_BUDP_3: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_MLTX_V1: 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_V2: 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 May 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Liddell Unit 4	1 May 2023	NSW	Deregistered Generator
Liddell Unit 2	1 May 2023	NSW	Deregistered Generator
Liddell Unit 1	1 May 2023	NSW	Deregistered Generator
Riverina Battery 2 (Gen Mode)	23 May 2023	NSW	New Battery
Riverina Battery 2 (Load Mode)	23 May 2023	NSW	New Battery
Darlington Point Battery (Load Mode)	30 May 2023	NSW	New Battery
Darlington Point Battery (Gen Mode)	30 May 2023	NSW	New Battery

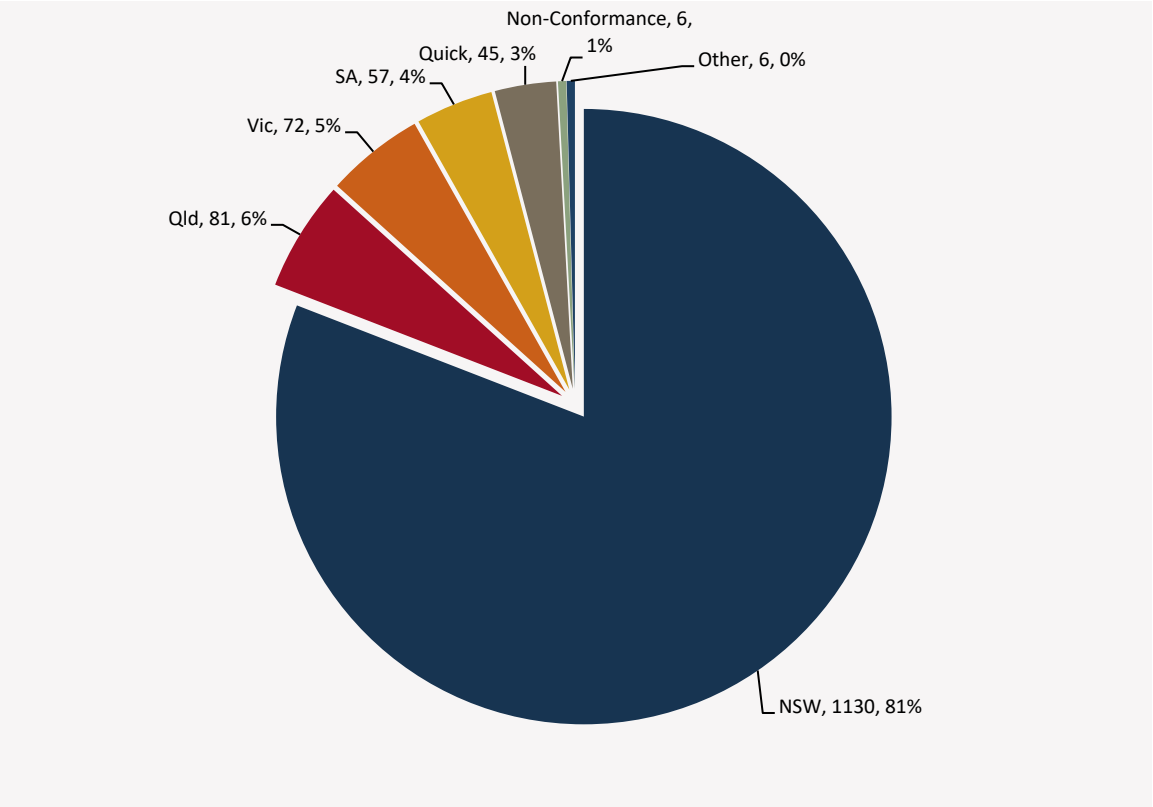
3.1 Constraint Equation Changes

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