Monthly Constraint Report

April 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 April 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
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)	2922 (243.5)	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	1731 (144.25)	Thermal
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.	1600 (133.33)	Transient 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	1190 (99.16)	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1112 (92.66)	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	1035 (86.25)	Thermal
N^^N_NIL_X5_BEKG	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 Kerang 220kV line and other nearby lines in NW Victoria	971 (80.91)	Voltage Stability
N>94K2_94T_NIL	Out= Parkes to Suntop (94K/2) 132kV line (Open at Parkes end only), avoid O/L on Molong to Orange North (94T) on trip of Nil, Feedback	930 (77.5)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	816 (68.0)	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.	778 (64.83)	Voltage Stability

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	1,625,485	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1,191,157	Thermal
N>94K2_94T_NIL	Out= Parkes to Suntop (94K/2) 132kV line (Open at Parkes end only), avoid O/L on Molong to Orange North (94T) on trip of Nil, Feedback	971,557	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	913,612	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	642,469	Thermal
N^^N_NIL_X5_BEKG	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 Kerang 220kV line and other nearby lines in NW Victoria	553,040	Voltage Stability
V_BANSF_BBD_S1	Out = Nil, Bannerton SF limitation segment 1 if Boundary Bend (BBD) loading is less than 5 MW, DS only. Swamp out if BBD loading is outside the range.	475,136	Discretionary
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	270,921	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.	269,632	Voltage Stability
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)	265,588	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
S_DLBAT-G_ISL	Out= Yorke Peninsula 132kV network islanded (i.e. island formed between Hummocks-Androssan West- Dalrymple 132kV network), Dalrymple Battery (Gen Mode) islanded	51 (4.25)	Islanding - Unit
S_DLBAT-L_ISL	Out= Yorke Peninsula 132kV network islanded (i.e. island formed between Hummocks-Androssan West- Dalrymple 132kV network), Dalrymple Battery (Load Mode) islanded	19 (1.58)	Islanding - Unit
S_WP_ISL	Out= Yorke Peninsula 132kV network islanded (i.e. island formed between Hummocks-Androssan West- Dalrymple 132kV network), Wattle Pt WF islanded	9 (0.75)	Islanding - Unit
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	2 (0.16)	FCAS
NSA_Q_GSTONE34_290	Gladstone 3 + 4 >= 290 for Network Support Agreement	1 (0.08)	Network Support
N_FINLYSF_FLT_93	Limit Finley solar farm upper limit to 93 MW to manage post contingent voltage oscillation	1 (0.08)	System Strength

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
S_DLBAT-G_ISL	Constraint equation violated for 51 non-consecutive DIs on 23/04/2023 from 0345 hrs to 1030 hrs with a max violation degree of 2.78 MW occurring on 23/04/2023 at 0705 hrs. Constraint violated due to the availability of Dalrymple Battery being less than the actual MW.
S_DLBAT-L_ISL	Constraint equation violated for 19 non-consecutive DIs on 23/04/2023 from 0335 hrs to 1050 hrs with a max violation degree of 4.21 MW occurring on 23/04/2023 at 0450 hrs. Constraint violated due to the availability of Dalrymple Battery being less than the actual MW.
S_WP_ISL	Constraint equation violated for 9 non-consecutive DIs on 23/04/2023 from 0340 hrs to 0450 hrs with a max violation degree of 1 MW occurring on 23/04/2023 at 0445 hrs. Constraint violated due to the availability of Wattle Point Wind Farm being less than the actual MW.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 2 non-consecutive DIs on 19/04/2023 at 1625 hrs and 29/04/2023 at 0200 hrs with a max violation degree of 10.48 MW. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
NSA_Q_GSTONE34_290	Constraint equation violated for 1 DI on 24/04/2023 at 1030 hrs with a violation degree of 20.93 MW. Constraint equation violated due to Gladstone unit 3 and 4 limited by its ramp rates.
N_FINLYSF_FLT_93	Constraint equation violated for 1 DI on 18/04/2023 at 1015 hrs with a violation degree of 3.15 MW. Constraint equation violated due to Finley Solar Farm exceeding the discretionary upper limit of 93 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)
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)	2787 (232.25)	-44.23 (-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	1186 (98.83)	-21.12 (-197.13)
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	1169 (97.42)	-879.08 (-1166.83)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1073 (89.42)	265.61 (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	956 (79.67)	-360.07 (-447.0)
N^^N_NIL_X5_BEKG	VIC1-NSW1 Export	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of Bendigo to Kerang 220kV line and other nearby lines in NW Victoria	869 (72.42)	331.29 (1211.29)
F_MAIN++NIL_BL_L60	T-V-MNSP1 Import	Mainland Lower 60 second Requirement for loss of Basslink, Basslink flow into Tas	783 (65.25)	-431.87 (-447.0)
N^^N_NIL_X5_BEKG	V-S-MNSP1 Import	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 Kerang 220kV line and other nearby lines in NW Victoria	733 (61.08)	115.99 (-154.9)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	686 (57.17)	324.37 (447.0)
S>NIL_MHNW1_MHNW2	V-S-MNSP1 Export	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	661 (55.08)	155.66 (185.72)

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_535465AD	21/04/2023 10:35 to 21/04/2023 10:40	CA_SYDS_535465AD was created to manage the overloading of Wagga-WaggaN 9R5 132kV Line for the loss of 901 Line.

Constraint Set ID	Date Time	Description
CA_BRIS_5347C6C8	11/04/2023 20:55 to 11/04/2023 23:00	CA_BRIS_5347C6C8 was created to manage the overloading of Hummocks -Snowtown-Bungama 132kV Line for the loss of Mintaro - Clare North 132kV Line during unplanned outage of Templers-Waterloo 132kV Line with an existing outage of Waterloo-Waterloo East 132 kV Line.

2.5.1 Further Investigation

CA_SYDS_535465AD: Constraint was invoked and not binding. Constraint was revoked after a constraint N-WNWGA_9R6 was modified to manage ongoing and future violation issues.

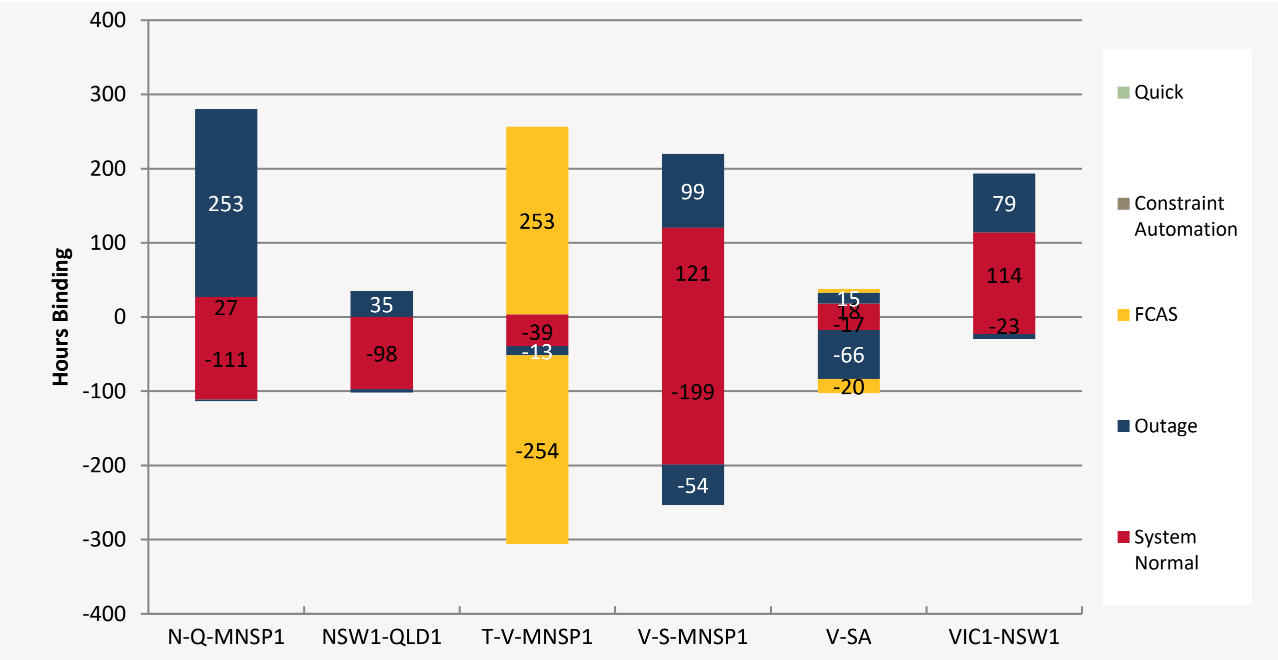
CA_BRIS_5347C6C8: Constraint was invoked and binding. Reviewed and no constraint changes required due to combination of planned and unplanned outages.

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.

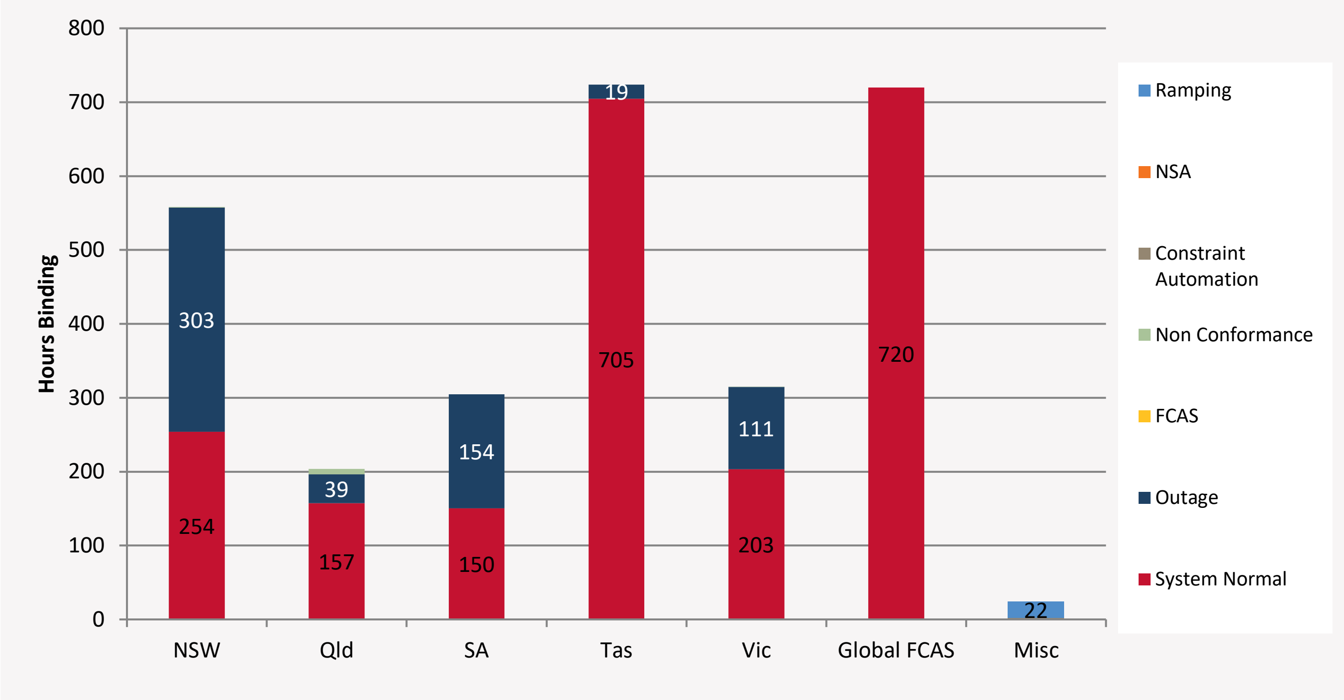
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

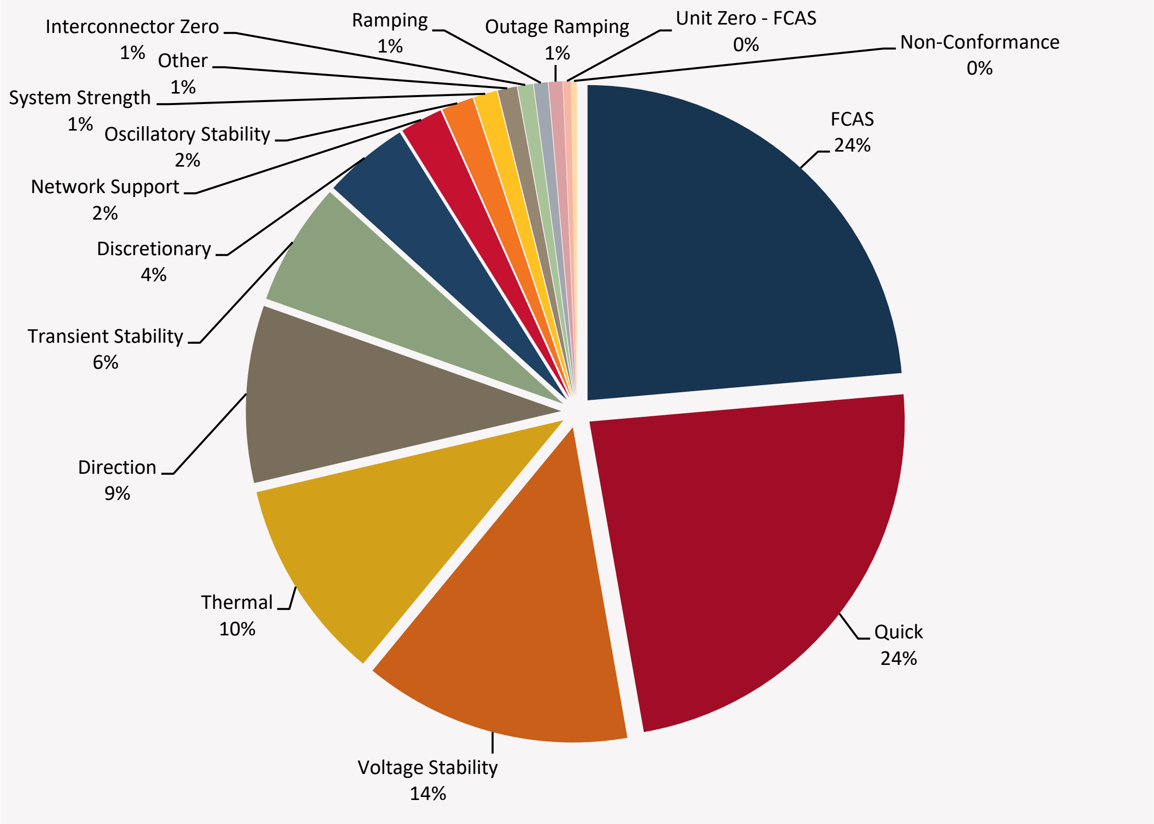
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

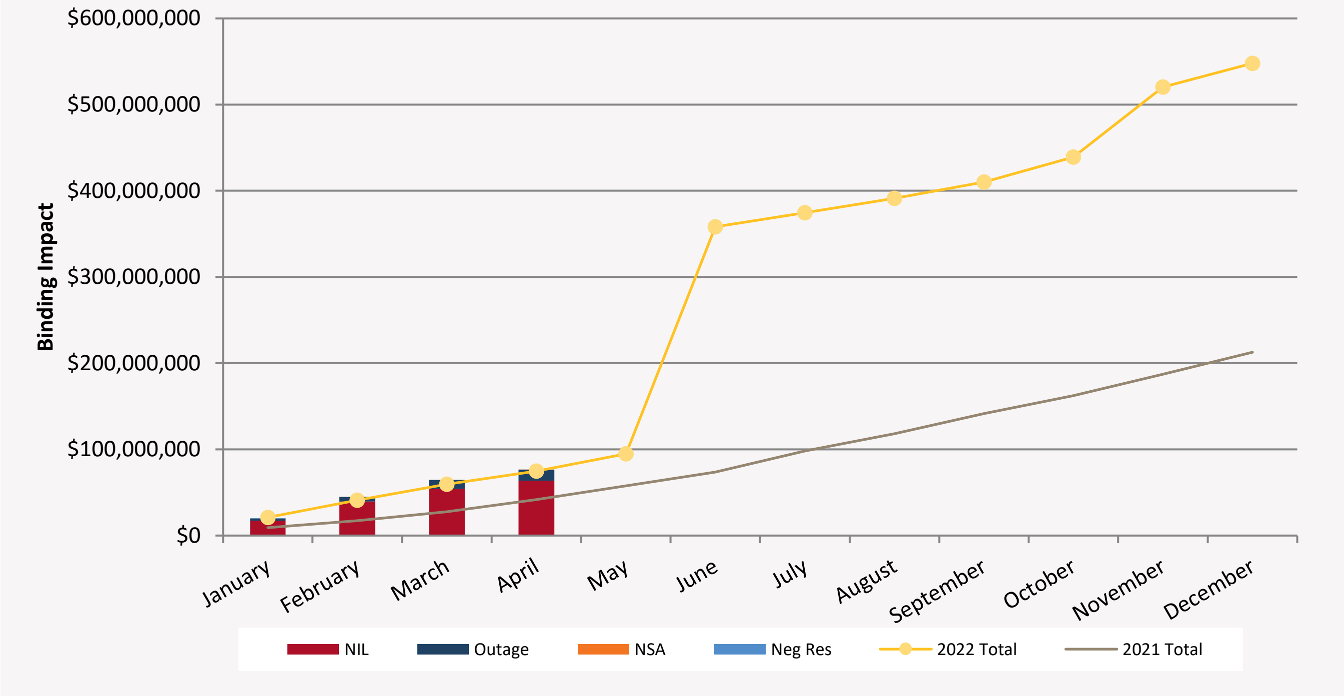
Figure 3 Binding by limit type



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
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.	62	7,961% (119.5)	5,021% (90.58)
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.	19	1,657% (9,431)	99.58% (558)
V::N_ROSM_O1	Out = Rowville to South Morang 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 220kV.	4	925% (161.19)	574% (147.8)
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.	9	460% (133.74)	104.17% (82.31)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_NIL_O1	Out = NIL, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 220kV.	42	416% (122.17)	25.26% (45.82)
V::N_HYTR_O1	Out = Heywood to Tarrone 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 220kV.	10	214% (215.9)	72.74% (75.96)
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)	252	192% (55.79)	39.73% (18.28)
V::N_NIL_O2	Out = NIL, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 500kV.	37	110.% (356.13)	20.32% (66.19)
V::N_HWSM_V1	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 220 kV.	3	79.92% (72.69)	64.58% (71.14)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

V::N_NIL_O1: 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.

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::N_HYTR_O1: 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.

T::T_NIL_1: 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 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Rye Park Substation	3 April 2023	NSW	Rye Park substation has been cut into the existing Gullen Range Wind Farm - Yass (3J) 330 kV Line to form the following circuits: Gullen Range Wind Farm - Rye Park (3P) 330 kV Transmission Line; Rye Park - Yass (3J) 330 kV Transmission Line.
Dulacca Wind Farm	4 April 2023	QLD	New Generator
Tarong - Chinchilla 132 kV Line	6 April 2023	QLD	H18 Tarong - T13 Chinchilla No.7168 132 kV Line and H18 Tarong - T13 Chinchilla No.7183 132 kV Line have been decommissioned.
Philip Island BESS Gen1	12 April 2023	VIC	New Battery
Philip Island BESS Load1	12 April 2023	VIC	New Battery
Torrens Island Battery (Generation Mode)	26 April 2023	SA	New Battery
Torrens Island Battery (Load Mode)	26 April 2023	SA	New Battery

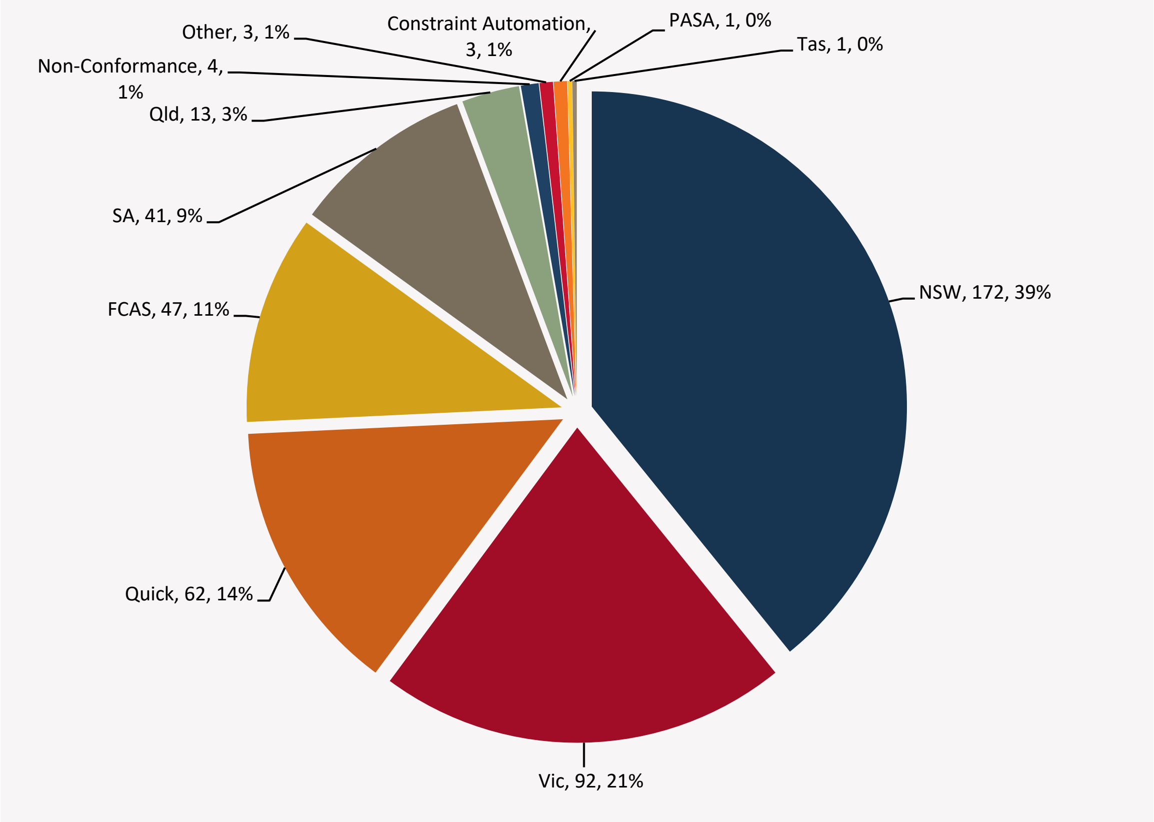
3.1 Constraint Equation Changes

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