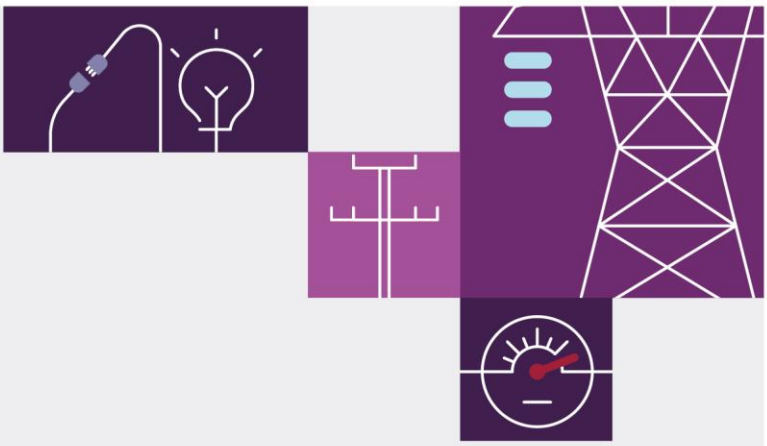
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

February 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 February 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)	2917 (243.08)	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.	2721 (226.75)	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	2341 (195.08)	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	2334 (194.5)	Thermal
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria	2159 (179.91)	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	2054 (171.16)	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2044 (170.33)	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	1552 (129.33)	Thermal
N>>DPTX1-2_TX_NIL	Out= one Darlington Pt 132/330kV TX1 or TX2, avoid O/L remaining Darlington Pt 132/330kV TX on trip of Nil, Feedback	1349 (112.41)	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	1288 (107.33)	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_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	2,332,527	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	2,034,907	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1,936,159	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.	1,795,731	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	1,568,704	Thermal
N>>NIL_970_051	Out= NIL, avoid O/L BurJK to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	1,520,392	Thermal
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria	1,505,345	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	1,444,258	Thermal
N>>DPTX1-2_TX_NIL	Out= one Darlington Pt 132/330kV TX1 or TX2, avoid O/L remaining Darlington Pt 132/330kV TX on trip of Nil, Feedback	1,149,972	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	1,123,425	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 (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.

[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.

Table 3 Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
Q_STR_KBWF_N-2	Out = Nil, Loss of 858 and 857 declared credible. Limit Kaban WF to 25% if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7, Kar>= 4 (1% if Kar>=2),NQLD>350&370(AVG),Ross_FN>150&170(AVG),Zero otherwise.	15 (1.25)	System Strength
N>NIL_999	Out= Nil, avoid O/L Bango999 to Cowra (999) on trip of Nil, Feedback	8 (0.66)	Thermal
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)	6 (0.5)	Voltage Stability
NC_S_BOWWPV1	Non Conformance Constraint for BOLIVAR WWTP PV1	6 (0.5)	Non-Conformance
Q_NIL_STRGTH_KBWF	Out = Nil, limit Kaban Wind farm output depends on the number units online in Stanwell, Callide B, Callide C, generators and Haughton Syncon, North Queensland demand. Zero if it does not meet the condition.	4 (0.33)	System Strength
Q_STR_7C8C_RUGSF	Limit Rugby Run Solar 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.	1 (0.08)	System Strength
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	1 (0.08)	FCAS
NSA_T_DVGATE_10	Devils Gate >= 10 MW for Network Support Agreement	1 (0.08)	Network Support
V^^SML_NIL_3	Out = Nil, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	1 (0.08)	Voltage Stability
F_T+NIL_WF_TG_R6	Out= Nil, Tasmania Raise 6 sec requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby, Waddamana to Cattle Hill or Pieman to Granville Harbour line, Basslink unable to transfer FCAS	1 (0.08)	FCAS

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
Q_STR_KBWF_N-2	Constraint equation violated for 15 non-consecutive DIs between 03/02/2023 1750 hrs and 04/02/2023 0045 hrs with violation degree of 0.001 MW. Constraint equation violated due to Kaban Wind Farm exceeding its MVAr limit.
N>NIL_999	Constraint equation violated for 8 non-consecutive DIs between 17/02/2023 1845 hrs and 19/02/2023 1905 hrs with max violation of 48.01MW occurring on 18/02/2023 at 1610. Constraint equation violated due to 132kV Line Bango999 to Cowra (999) exceeding its limit.
N^N-LS_SVC	The constraint equation violated for 5 non-consecutive DIs between 12/02/2023 1750 hrs and 12/02/2023 1810 hrs and 1 DI on 27/02/2023 at 1740 hrs with max violation degree of 19.98 MW occurring on 27/02/2023 at 1740 hrs. Constraint violated due to competing requirements with the import limits on Directlink which were set by Q>NIL_757_758_ECS, N_X_MBTE_3B.
NC_S_BOWWPV1	Constraint equation violated for 6 non-consecutive DIs between 02/02/2023 1155 hrs to 02/02/2023 1240 hrs with max violation of 0.14 MW occurring on 02/02/2023 at 1155 hrs. Constraint violated due to Bolivar WWTP PV1 non-conforming.
Q_NIL_STRGTH_KBWF	The constraint equation violated for 4 consecutive DIs between 03/02/2023 1755 hrs and 03/02/2023 1805 hrs with violation degree of 0.001 MW. Constraint equation violated due to Kaban wind farm exceeding its MVAr limit.

Constraint Equation ID (System Normal Bold)	Description
Q_STR_7C8C_RUGSF	The constraint equation violated for 1 DI on 11/02/2023 at 0835 hrs with violation degree of 18.97 MW. Constraint equation violated due to Rugby Run Solar Farm being limited by its ramp down rate.
F_T_AUFLS2_R6	The constraint equation violated for 1 DI on 02/02/2023 at 0805 hrs with violation degree of 9.67 MW. The constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
NSA_T_DVGATE_10	The constraint equation violated for 1 DI on 02/02/2023 at 0715 hrs with violation degree of 5 MW. Constraint equation violated due to the Devils Gate hydro unit limited by its ramp up rate.
V^^SML_NIL_3	The constraint equation violated for 1 DI on 15/02/2023 at 1845 hrs with violation degree of 4.21 MW. Constraint equation violated due to competing requirement on Murraylink DC interconnector import limit which was set by SVML_ROC_80.
F_T+NIL_WF_TG_R6	The constraint equation violated for 1 DI on 01/02/2023 at 0315 hrs with max violation degree of 3.18 MW. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.

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)	2816 (234.67)	-61.07 (85.22)
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	2030 (169.17)	172.0 (205.12)
N^^N_NIL_3	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 any major 220kV line in NW Victoria	1637 (136.42)	-95.25 (1061.46)
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.	1614 (134.5)	157.46 (-103.52)
F_T++NIL_BL_R60_3	T-V-MNSP1 Import	Tasmania Raise 60 second Requirement for loss of Basslink, Segment 3, FCSPS available	1146 (95.5)	-432.41 (-447.01)
N^^N_NIL_3	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 any major 220kV line in NW Victoria	1110 (92.5)	161.26 (-133.35)
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	993 (82.75)	-421.53 (-447.01)
S>NIL_NWRB2_NWRB1	V-S-MNSP1 Export	Out= NIL, avoid O/L North West Bend-Roberstown #1 132kV line on trip of North West Bend-Robertstown #2 132kV line (this trips MWP1-3 SFs), Feedback	745 (62.08)	157.66 (197.67)
F_T++NIL_BL_R6_3	T-V-MNSP1 Import	Tasmania Raise 6 second Requirement for loss of Basslink, Segment 3, FCSPS available	648 (54.0)	-436.52 (-447.01)
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	605 (50.42)	-175.91 (486.75)

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_52F01146	04/02/2023 08:10 to 04/02/2023 08:15	Constraint Automation was created to manage overloading on ARTS-WBTS 220 kV line for the loss of BETS-KGTS 220 kV line.

2.5.1 Further Investigation

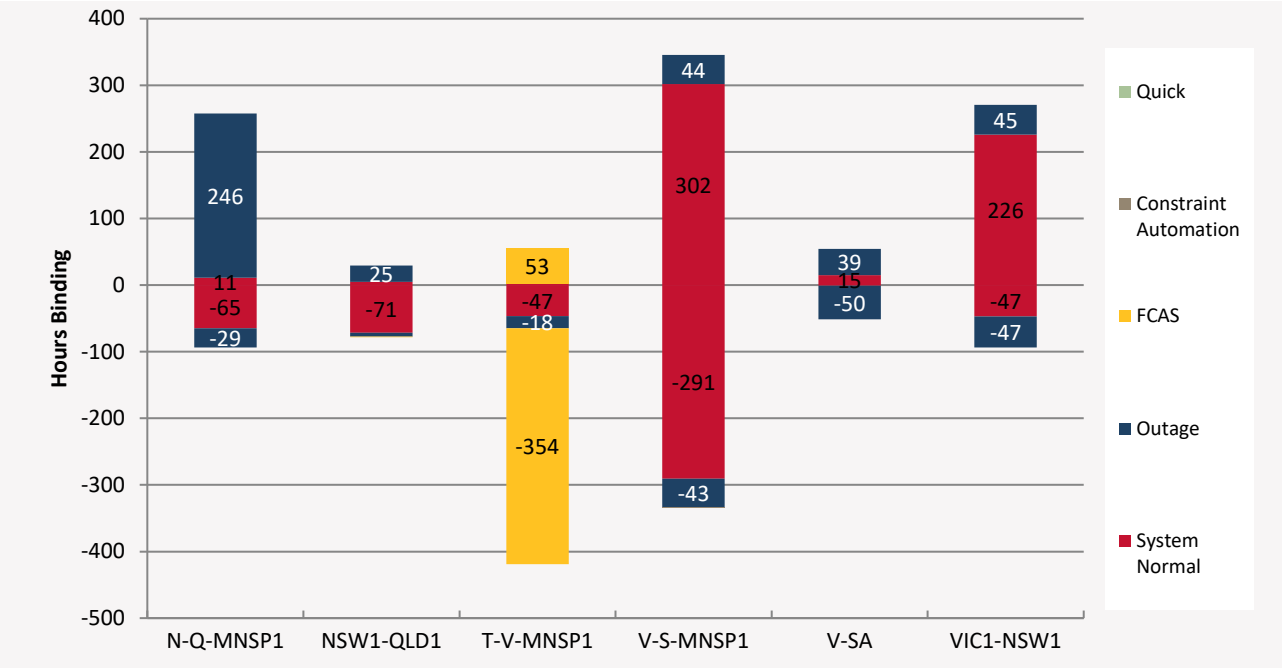
CA_SYDS_52F01146: Auto Constraint was invoked and binding. Constraint builder confirmed the relevant constraint was working correctly and the violation was due to Murraylink VFRB. When this was removed, the violation was resolved.

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.

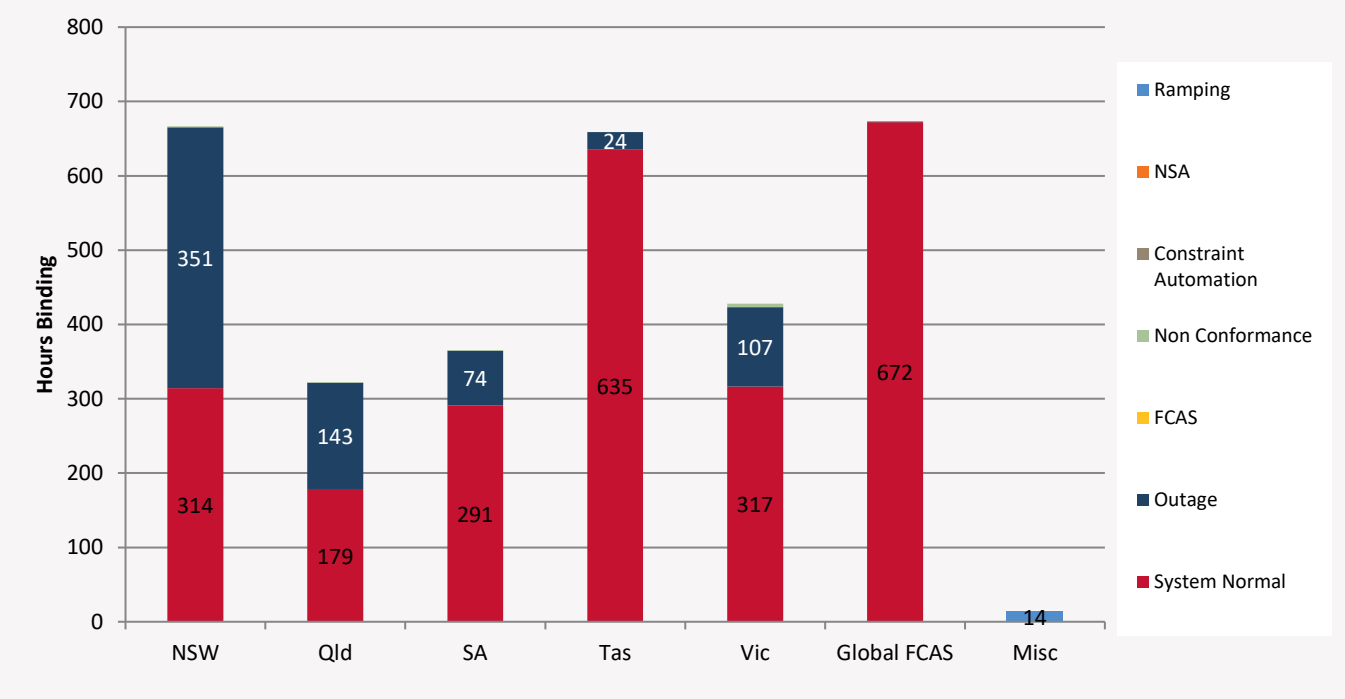
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

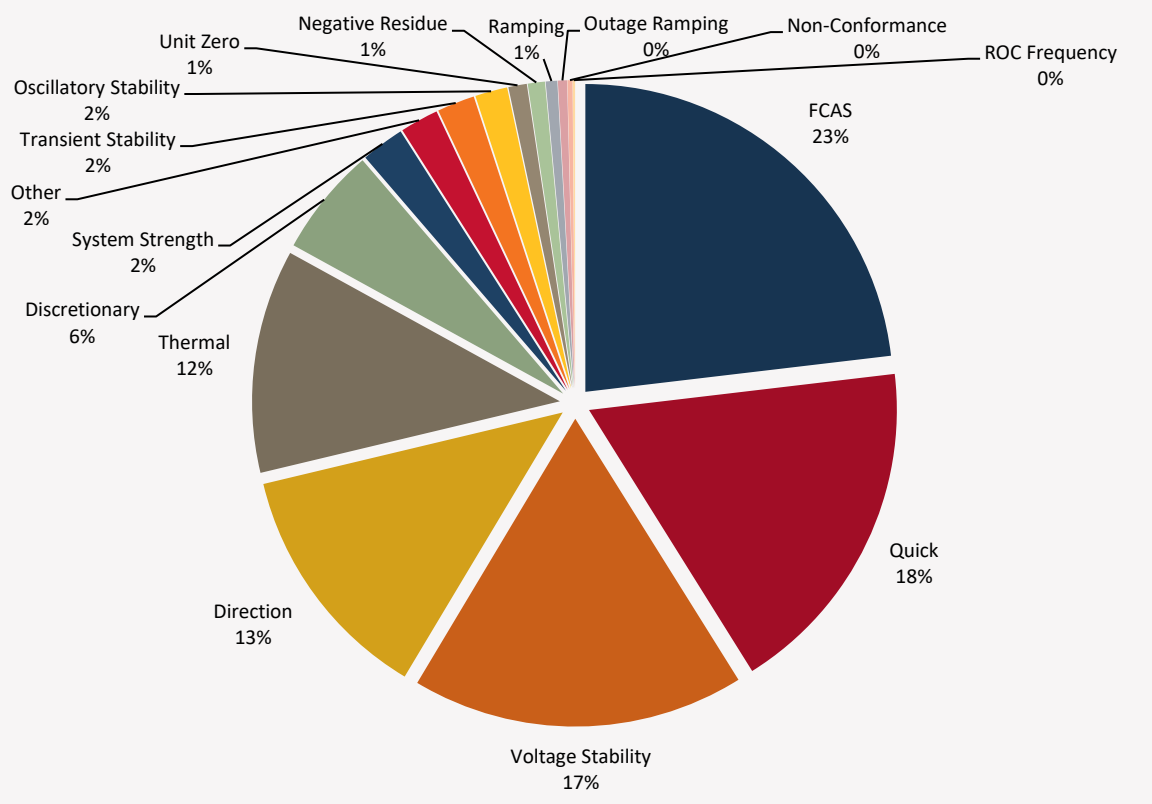
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

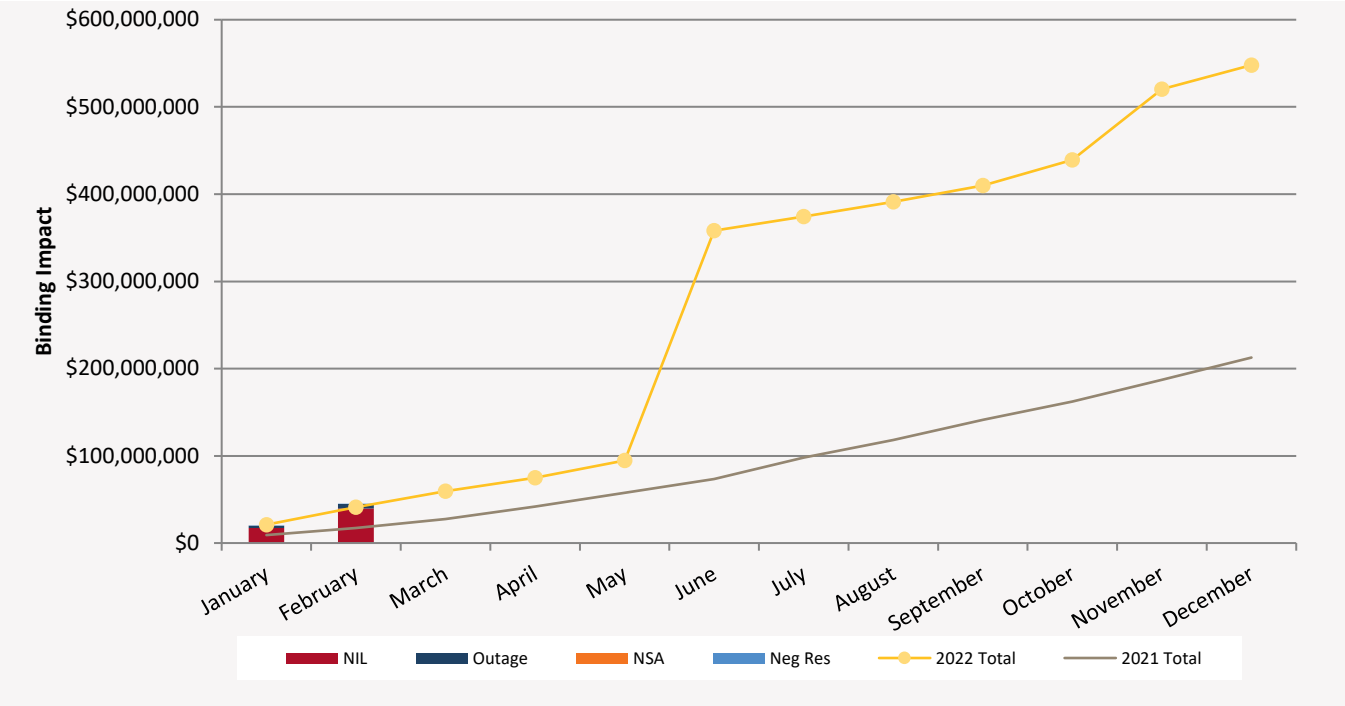
Figure 3 Binding by limit type



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_X_SMSC_O1	Out = both South Morang 330 kV series capacitor banks, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 220kV.	50	10,347% (115.54)	271% (48.11)
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)	563	9,433% (117.99)	142.31% (28.77)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	188	3,291% (447.47)	24.5% (33.04)
V::N_X_SMSC_V1	Out = both South Morang 330 kV series capacitor banks, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates. Yallourn W G1 on 220kV.	20	2,430% (129.02)	167% (42.43)

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	20	266% (28.8)	125.49% (19.96)
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	66	151% (288.14)	84.11% (182.73)
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.	83	131.18% (341.83)	64.85% (185.63)
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	32	128.51% (49.74)	28.59% (23.49)
N^^V_DTSS_1	Out = Dapto-Sydney South(11), avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	7	111.01% (337.63)	59.25% (196.55)

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.

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

N^^V_DTSS_1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_X_SMSC_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.

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.

V::N_X_SMSC_V1: Investigated and no improvement can be made to the constraint equation at this stage.

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^^SML_NSWRB_2: Investigated and no improvement can be made to the constraint equation at this stage.

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 February 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Hazelwood Battery (Generation Component)	7 February 2023	VIC	New Battery
Hazelwood Battery (Load Component)	7 February 2023	VIC	New Battery
Tailem Bend Battery (Gen Component)	28 February 2023	SA	New Generator
Tailem Bend Battery (Load Component)	28 February 2023	SA	New Load
Strathmore No.2 275/132 kV Transformer	16 February 2023	QLD	
Cultana – Yadnarie – Port Lincoln No. 2 132kV line	22 February 2023	SA	

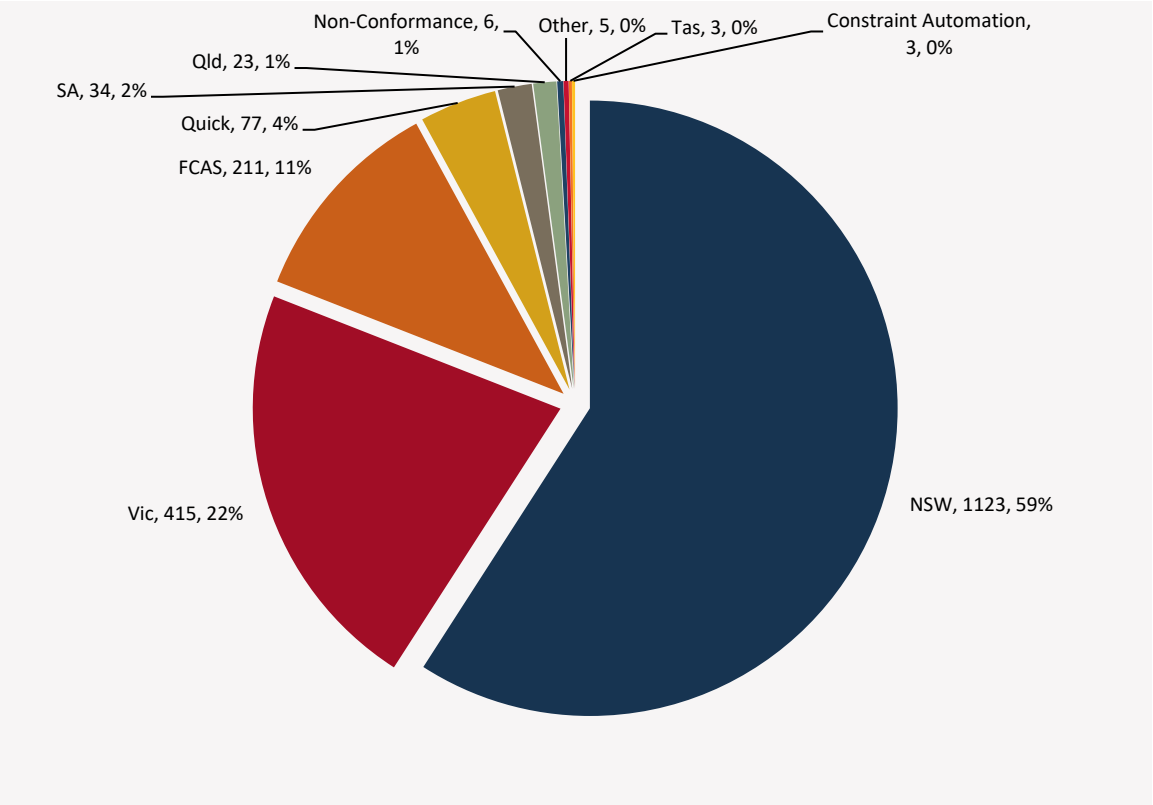
3.1 Constraint Equation Changes

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