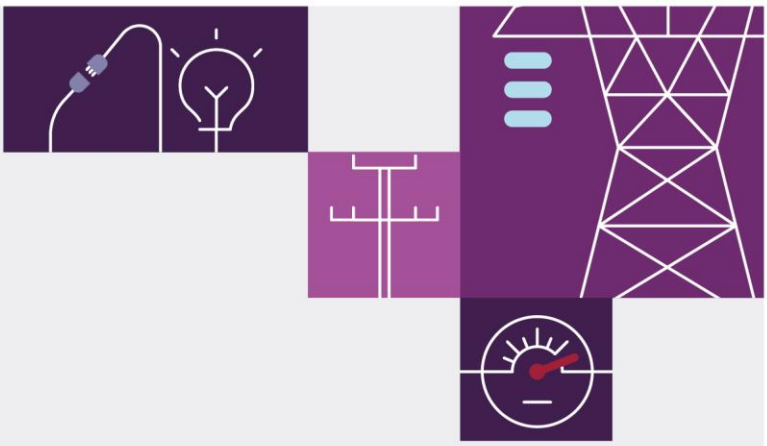
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

June 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 June 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
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.	4112 (342.66)	Transient Stability
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)	3877 (323.08)	Voltage Stability
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.	2694 (224.5)	System Strength
SVML^NIL_MH-CAP_ON	Out=NIL, SA to Vic on ML upper transfer limit to manage voltage collapse at Monash (Note: applies when capacitor banks at Monash are available and I/S for switching.)	1462 (121.83)	Voltage Stability
V^^N_LTUT_1	Out = Lower to Upper Tumut (64) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	1204 (100.33)	Voltage Stability
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	1200 (100.0)	Interconnector Zero
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	995 (82.91)	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)	890 (74.16)	Thermal
S>>RBTU_RBPA_WTTP	Out= Robertstown-Tungkillo 275kV line, avoid O/L Waterloo-Templers 132kV on trip of Robertstown-Para 275kV line, Feedback	808 (67.33)	Thermal

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
V^^N_DTKV_1	Out = Dapto - Kangaroo Valley (18) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	751 (62.58)	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
S>>RBTU_TWPA_TPRS	Out= Robertstown-Tungkillo 275kV line, avoid O/L Templers-Roseworthy 132kV line on trip of Templers West-Para 275kV line, Feedback	771,095	Thermal
S_DVRB2_270	Out = DV-LK 275kV line Or CN-RB 275kV line O/S, discretionary upper limit for Hornsdale WF1+ Hornsdale WF2+Hornsdale WF3+Hallet Hill GT + Hornsdale battery (i.e. generation + load component) <= 270 MW	660,438	Discretionary
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)	570,326	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	561,170	Voltage Stability
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)	487,248	Discretionary
SVML^NIL_MH-CAP_ON	Out=NIL, SA to Vic on ML upper transfer limit to manage voltage collapse at Monash (Note: applies when capacitor banks at Monash are available and I/S for switching.)	343,295	Voltage Stability
S>>RBTU_RBPA_WTTP	Out= Robertstown-Tungkillo 275kV line, avoid O/L Waterloo-Templers 132kV on trip of Robertstown-Para 275kV line, Feedback	329,786	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	230,206	Thermal
V_KIAMSF_DYN	Out = Kiamal Syncon, Limit Kiamal solar farm to 135 MW when Murra Warra 2 WF syncon I/S. Limit Kiamal solar farm to 100 MW when Murra Warra 2 WF syncon O/S	221,942	Discretionary
V>>NIL_ARWB_KGBE	Out= Nil, avoid O/L Ararat to Waubra 220kV line on trip of Kerang to Bendigo 220kV line, Feedback	215,433	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_NEWENSF1+2_100-INV	Constraint to violate if New Engliand Solar Farm 1 and 2 inverter availability greater than 100. Dispatch only. swamped out otherwise. DS only.	16 (1.33)	System Strength
N_METZSF_20INV	Constraint to violate if Metz Solar Farm inverter availability greater than 20. Constraint swamp out otherwise. DS only	5 (0.41)	System Strength
N_FINLEYSF_49_INV	Limit Finley Solar Farm upper limit to 0 MW if number of inverter available exceed 49. Dispatch only. swamped out if Inverters are within the limit.	4 (0.33)	System Strength
N_HILLSTSF1_0INV	Constraint to violate if Hillston 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
N_FINLEYSF_80INV	Limit Finley Solar Farm upper limit to 0 MW if number of inverter available exceed 80 Dispatch only. swamped out if Inverters are within the limit.	3 (0.25)	System Strength
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
N_AVLSF1_0INV	Constraint to violate if Avonlie Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	2 (0.16)	System Strength
N_MOREESF1_21INV	Limit Moree Solar Farm upper limit to 0 MW if number of inverter available exceed 21. Constraint swamp out otherwise.	2 (0.16)	System Strength
N_FINLYSF_FLT_55	Limit Finley solar farm upper limit to 55 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
N_NEWENSF1+2_100-INV	Constraint equation violated for 16 non-consecutive DIs from 07/06/2023 0405 hrs to 28/06/2023 1035 hrs with a violation degree of 0.001 MW. Constraint equation violated due to New England Solar Farm 1 and 2 exceeding its inverter limit.
N_METZSF_20INV	Constraint equation violated for 5 consecutive DIs on 26/06/2023 from 0735 hrs to 0755 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Metz Solar Farm exceeding its inverter limit.
N_FINLEYSF_49_INV	Constraint equation violated for 4 non-consecutive DIs on 23/06/2023 from 0830 hrs to 0855 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Finley Solar Farm exceeding its inverter limit.
N_HILLSTSF1_0INV	Constraint equation violated for 4 consecutive DIs on 20/06/2023 from 1840 hrs to 1855 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Hillston Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
N_WSTWYSF1_0INV	Constraint equation violated for 4 non-consecutive DIs on 22/06/2023 from 0705 hrs to 1015 hrs with a violation degree of 0.001 MW. Constraint equation violated due to West Wyalong Solar Farm exceeding its inverter limit.
N_FINLEYSF_80INV	Constraint equation violated for 3 consecutive DIs on 20/06/2023 from 0835 hrs to 0545 hrs with a max violation degree of 22.72 MW occurring on 20/06/2023 at 0835 hrs. Constraint equation violated due to Finley Solar Farm exceeding its inverter limit.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 2 consecutive DIs on 29/06/2023 at 1215 hrs and 1220 hrs with a max violation degree of 14.49 MW occurring on 29/06/2023 at 1215 hrs. Constraint equation violated due to Tasmania raise 6 sec service availability less than requirement.
N_AVLSF1_0INV	Constraint equation violated for 2 consecutive DIs on 22/06/2023 at 0705 hrs and 0710 hrs with a violation degree of 0.001 MW. Constraint violated due to Avonlie Solar Farm exceeding its inverter limit.
N_MOREESF1_21INV	Constraint equation violated for 2 consecutive DIs on 26/06/2023 at 1720 hrs and 1725 hrs with a violation degree of 0.001 MW. Constraint violated due to Moree Solar Farm exceeding their inverter limit.
N_FINLYSF_FLT_55	Constraint equation violated for 1 DI on 09/06/2023 at 1315 hrs with a violation degree of 14.03 MW. Constraint equation violated due to Finley Solar Farm being limited by its ramp down rate.

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)	3776 (314.67)	-85.21 (-29.0)
SVML^NIL_MH-CAP_ON	V-S-MNSP1 Import	Out=NIL, SA to Vic on ML upper transfer limit to manage voltage collapse at Monash (Note: applies when capacitor banks at Monash are available and I/S for switching.)	1349 (112.42)	-153.64 (-185.56)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1286 (107.17)	302.52 (447.0)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	1161 (96.75)	0.0 (0.0)
V^^N_LTUT_1	VIC1-NSW1 Export	Out = Lower to Upper Tumut (64) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	1055 (87.92)	1043.41 (1432.12)
V^^N_LTUT_1	V-S-MNSP1 Export	Out = Lower to Upper Tumut (64) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	1027 (85.58)	-80.14 (168.19)
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	864 (72.0)	495.04 (1253.42)
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	758 (63.17)	-254.65 (-447.01)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	741 (61.75)	203.99 (447.0)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	733 (61.08)	355.93 (447.01)

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

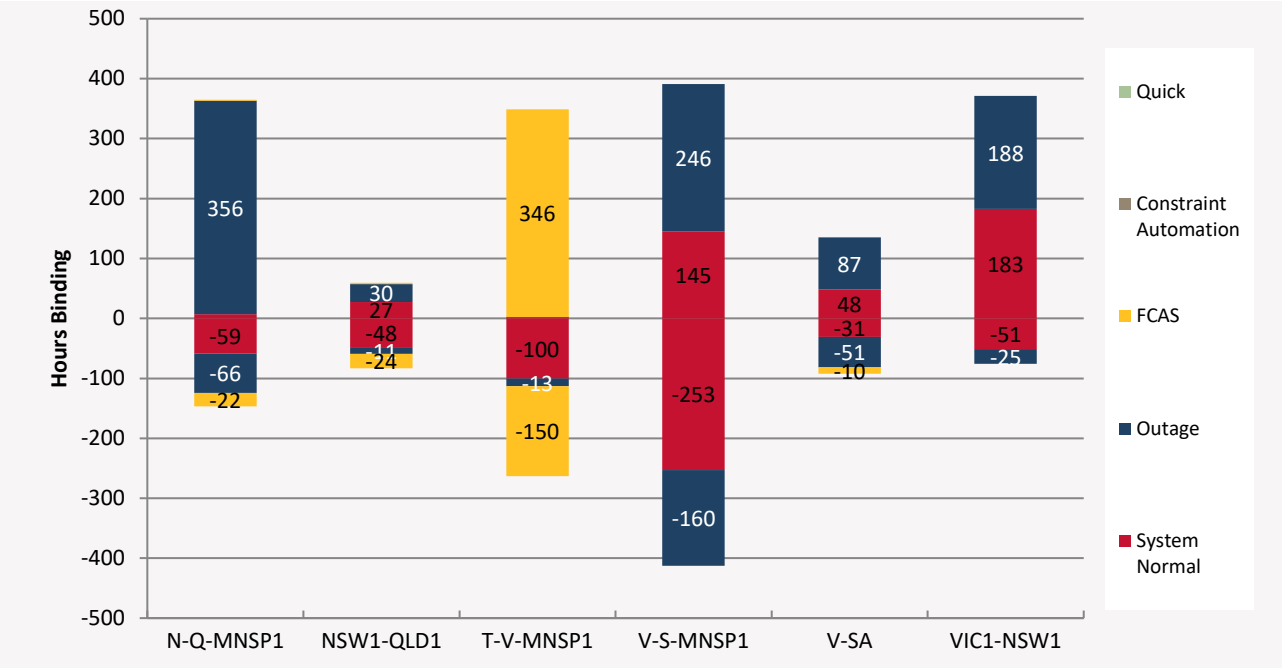
Non-real time constraint automation was not used.

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.

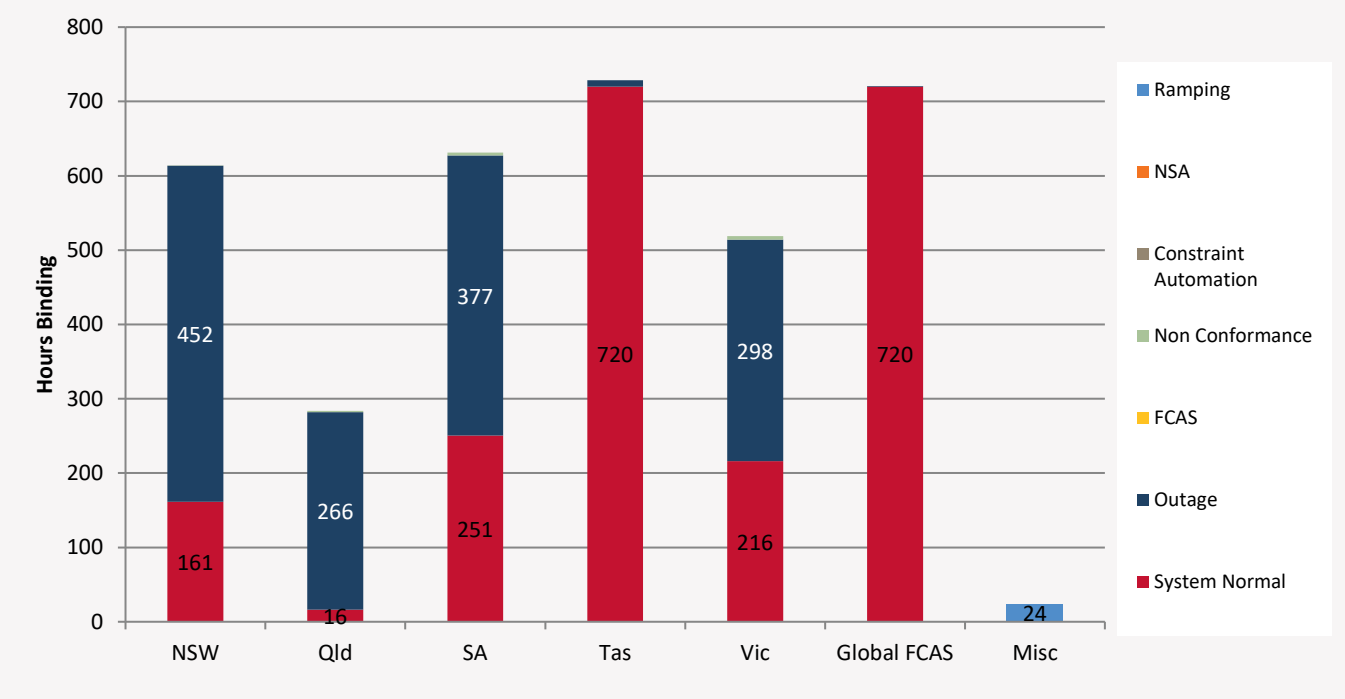
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

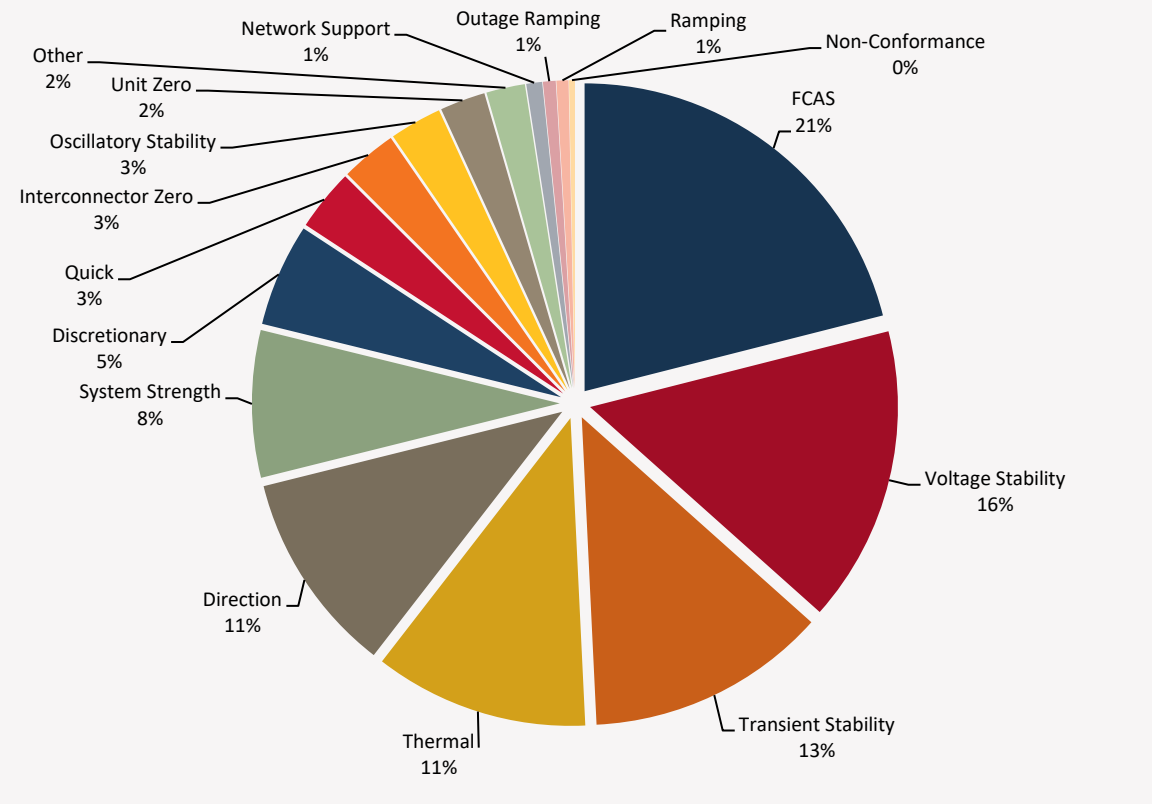
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

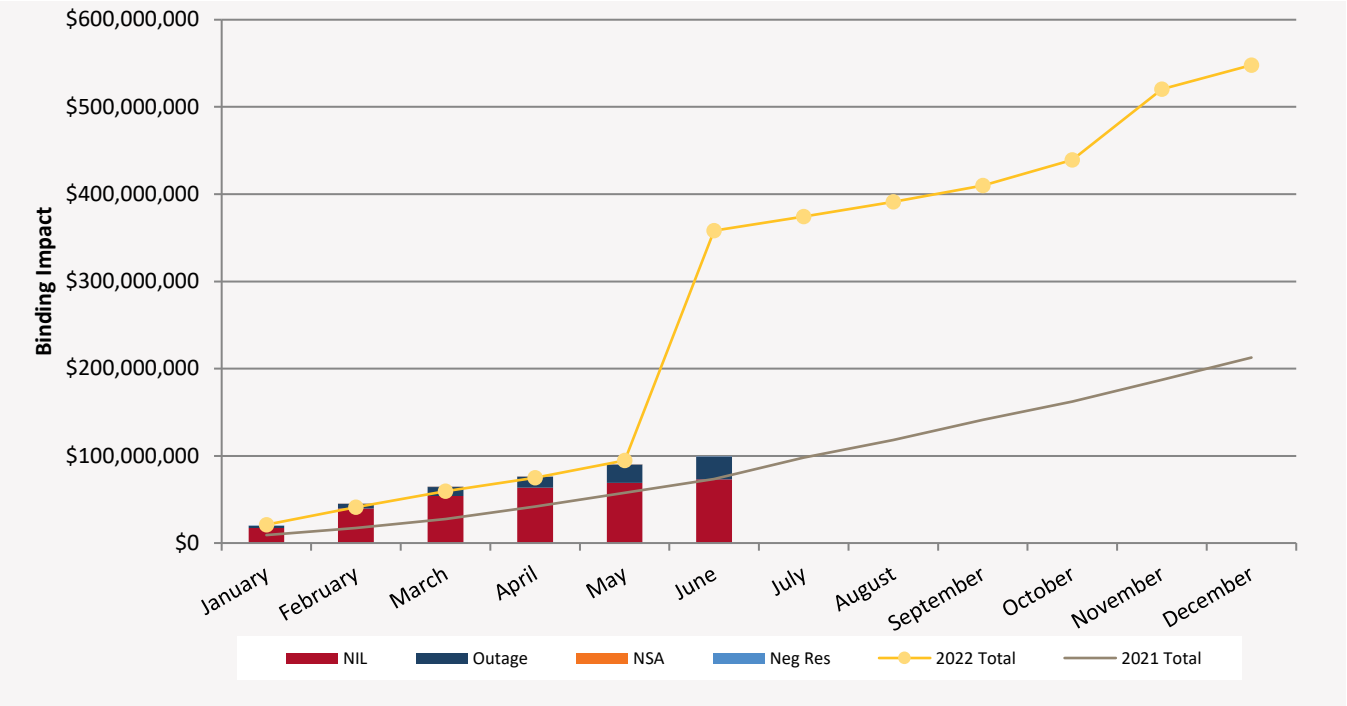
Figure 3 Binding by limit type



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.	9	7,961% (119.49)	7,961% (119.49)
V::N_NIL_V2	Out = NIL, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates. Yallourn W G1 on 500kV.	68	1,786% (244.48)	81.79% (70.97)
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.	115	1,585% (209.78)	46.37% (53.55)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	98	670% (12.6)	41.98% (4.91)
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)	768	376% (109.)	42.73% (23.85)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	32	366% (213.88)	58.23% (78.94)
N^^V_CNCW_1	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W) or Dapto-Kangaroo Valley (18), avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	67	212% (442.79)	54.49% (140.29)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	128	150.% (26.9)	26.82% (5.92)
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.	921	115.78% (325.7)	8.59% (44.04)

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_O2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_NIL_V2: 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.

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

N^^V_CNCW_1: 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.

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 June 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Tailem Bend – Tungkillo No. 1 275 kV Line	4 June 2023	SA	Transmission line commissioned
Tailem Bend – Cherry Gardens 275 kV Line	4 June 2023	SA	Transmission line decommissioned
Wyalong Solar Farm	6 June 2023	NSW	New Generator
Tungkillo – Cherry Gardens 275 kV line	19 June 2023	SA	Transmission line commissioned
Ross 275/132 kV No. 8 transformer	30 June 2023	QLD	Transformer commissioned

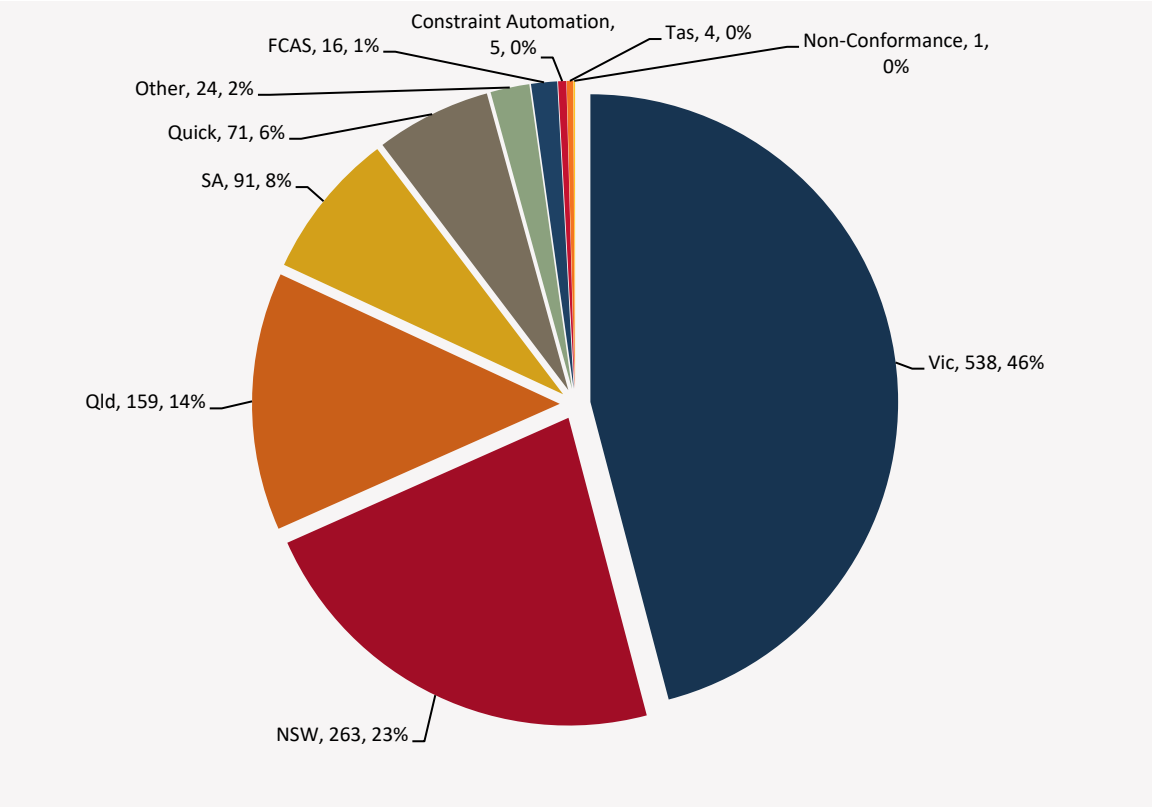
3.1 Constraint Equation Changes

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