AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

August 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 August 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 TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	3394 (282.83)	Voltage Stability
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.	3140 (261.66)	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	1796 (149.66)	Thermal
V::S_SETB_TBSE_2	Out= one South East to Tailem Bend 275kV line (NOTE: with both Black Range series capacitors O/S or I/S); Vic to SA Transient Stability limit for loss of one of the Tailembend-South East 275kV lines (South East Capacitor Available).	1436 (119.66)	Transient 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	1401 (116.75)	Thermal
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1118 (93.16)	Voltage Stability
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1034 (86.16)	Thermal
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	994 (82.83)	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 [Note: swamped with 96M or 9UJ or 9UH is O/S]	796 (66.33)	Thermal
S^^V_SETB_1	Out= one South East to Tailem Bend 275kV line, voltage collapse equation Tailem Bend-Keith #2 132kV Line <=135 MW on trip of other Tailem Bend-	766 (63.83)	Thermal

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
	South East 275kV line, Feedback (Note: with both SE series caps I/S or O/S)		

2.2 Top 10 binding impact constraint equations

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

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

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

Table 2 Top 10 binding impact network constraint equations

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Limit Type
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1,050,775	Thermal
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520 [Note: swamped with 96M or 9UJ or 9UH is O/S]	739,986	Thermal
V::S_SETB_TBSE_2	Out= one South East to Tailem Bend 275kV line (NOTE: with both Black Range series capacitors O/S or I/S); Vic to SA Transient Stability limit for loss of one of the Tailembend-South East 275kV lines (South East Capacitor Available).	681,053	Transient 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.	617,404	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	564,117	Thermal
V_CWWF_ISL_0	Crowlands Wind Farm total upper limit of 0 MW to manage risk of islanding on the next contingency	444,548	Islanding - Unit
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	436,532	Thermal
V_KIATA_ISL_0	Kiata Wind Farm upper limit of 0 MW to manage risk of islanding on the next contingency	414,706	Islanding - Unit
N>X-968+96M_969_NIL	Out= 968 (Tamworth to Narrabri) 132 kV Line and 96M(Narrabri to Moree), avoid O/L on 969 (Gunnedah to Tamworth) 132 kV on Nil trip, Feedback	364,789	Thermal
V_ARARATWF_ISL_0	Limit Ararat Wind Farm upper limit to 0 MW to manage risk of islanding on the next contingency	339,946	Islanding - Unit

[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
Q_STR_7C0K_KBWF_1	Limit 40% to Kaban WF if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7,Kar>=2, NQLD>350&370(AVG),Ross_FN>150&170(AVG)(80% if Syncon ON, 1% if Kar<0,100% at night),25% (40% if Haughton Synon ON)NQLD>250&270(AVG),Ross_FN>100&120(AVG) ,Zero otherwise.	15 (1.25)	System Strength
Q_STR_7C2K_KBWF_12	No limit to Kaban if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7,Kar >=2, NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton syncon ON(Haughton syncon OFF 50% daytime,100% at night) ,1% if Kar < 2 or Kareeya >=2, NQLD>250&Ross_FN>100, Zero otherwise.	15 (1.25)	System Strength
N>>DP_TIETX_D	Out= DarlingtonPt tie Tx(#3 or #4), avoid the remaining tie Tx O/L (220 KV to 330 kV) on Kerang-Bendigo trip; Feedback	11 (0.91)	Thermal
N_MOREESF1_21INV	Limit Moree Solar Farm upper limit to 0 MW if number of inverter available exceed 21. Constraint swamp out otherwise.	10 (0.83)	System Strength
N_MOREESF1_20INV	Limit Moree Solar Farm upper limit to 0 MW if number of inverter available exceed 20. Constraint swamp out otherwise.	8 (0.66)	System Strength
N_GOONSF1_0INV	Constraint to violate if Goonumbla Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	7 (0.58)	System Strength
Q>N-MUTE_758	Out= 758 T174 Terranora to H4 Mudgeeraba 110kV line, avoid O/L on remaining Terranora to Mudgeeraba line on trip of Condong generator.	6 (0.5)	Thermal
Q_STR_7C0K_RRSF_1	No limit to Ross River Solar Farm if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7,Kareeya >=2 (80% if Kareeya =0), NQLD>350&370(AVG),Ross_FN>150&170(AVG),25% (40% if Haughton Synon ON)NQLD>250&270(AVG),Ross_FN>100&120(AVG) ,Zero otherwise.	5 (0.41)	System Strength
N_NEWENSF1+2_110-INV	Constraint to violate if New Engliand Solar Farm 1 and 2 inverter availability greater than 110. Dispatch only. swamped out otherwise. DS only.	4 (0.33)	System Strength
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

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
Q_STR_7C0K_KBWF_1	Constraint equation violated for 15 consecutive DIs on 20/08/2023 from 1320 hrs to 1430 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Kaban Wind Farm exceeding its MVar limit.
Q_STR_7C2K_KBWF_12	Constraint equation violated for 15 consecutive DIs on 20/08/2023 from 1320 hrs to 1430 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Kaban Wind Farm exceeding its MVar limit.
N>>DP_TIETX_D	Constraint equation violated for 11 consecutive DIs on 17/08/2023 from 0805 hrs to 0855 hrs with a maximum violation degree of 195.04 MW occurring on 17/08/2023 at 0810 hrs. Constraint equation violated due to competing requirement on Murraylink DC interconnector import limit which was set by V^^SML_NIL_3.

Constraint Equation ID (System Normal Bold)	Description
N_MOREESF1_21INV	Constraint equation violated for 10 consecutive DIs on 03/08/2023 from 0735 hrs to 0820 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Moree Solar Farm exceeding its inverter limit.
N_MOREESF1_20INV	Constraint equation violated for 8 consecutive DIs on 01/08/2023 from 0720 hrs to 0755 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Moree Solar Farm exceeding its inverter limit.
N_GOONSF1_0INV	Constraint equation violated 7 non-consecutive DIs on from 16/08/2023 0735 hrs to 18/08/2023 1315 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Goonumbla Solar Farm exceeding its inverter limit.
Q>N-MUTE_758	Constraint equation violated for 6 consecutive DIs on 14/08/2023 from 1800 hrs to 1825 hrs with a maximum violation degree of 2.78 MW occurring on 14/08/2023 at 1805 hrs. Constraint equation violated due to competing requirement on Terranora Interconnector export limit which was set by N^N-LS_SVC.
Q_STR_7C0K_RRSF_1	Constraint equation violated for 5 consecutive DIs on 20/08/2023 from 1335 hrs to 1355 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Ross River Solar Farm exceeding its MVar limit.
N_NEWENSF1+2_110-INV	Constraint equation violated for 4 non-consecutive DIs on 03/08/2023 from 0735 hrs to 1020 hrs with a max violation degree of 46.16 MW occurring on 03/08/2023 at 1015 hrs. Constraint equation violated due to New England Solar Farm 1 and 2 exceeding their inverter limit.
N_BROKENH1_0INV	Constraint equation violated for 4 non-consecutive DIs from 17/08/2023 0805 hrs to 22/08/2023 0640 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Broken Hill Solar Farm exceeding its inverter 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 TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	3394 (282.83)	-40.09 (-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	1742 (145.17)	-25.93 (-191.14)
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	1716 (143.0)	-799.33 (-1199.17)
V::S_SETB_TBSE_2	V-SA Export	Out= one South East to Tailem Bend 275kV line (NOTE: with both Black Range series capacitors O/S or I/S); Vic to SA Transient Stability limit for loss of one of the Tailembend-South East 275kV lines (South East Capacitor Available).	1392 (116.0)	57.77 (135.6)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1346 (112.17)	355.46 (462.0)
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	1276 (106.33)	168.39 (189.46)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	973 (81.08)	1161.75 (1646.56)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	956 (79.67)	-55.49 (178.29)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	865 (72.08)	344.72 (462.0)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	826 (68.83)	0.0 (0.0)

2.5 Constraint Automation Usage

The constraint automation is an application in AEMO's energy management system (EMS) which generates thermal overload constraint equations based on the current or planned state of the power system. It is currently used by on-line staff to create thermal overload constraint equations for power system conditions where there were no existing constraint equations or the existing constraint equations did not operate correctly.

The following section details the reason for each invocation of the non-real time constraint automation constraint sets and the results of AEMO's investigation into each case.

Non-real time constraint automation was not used.

2.5.1 Further Investigation

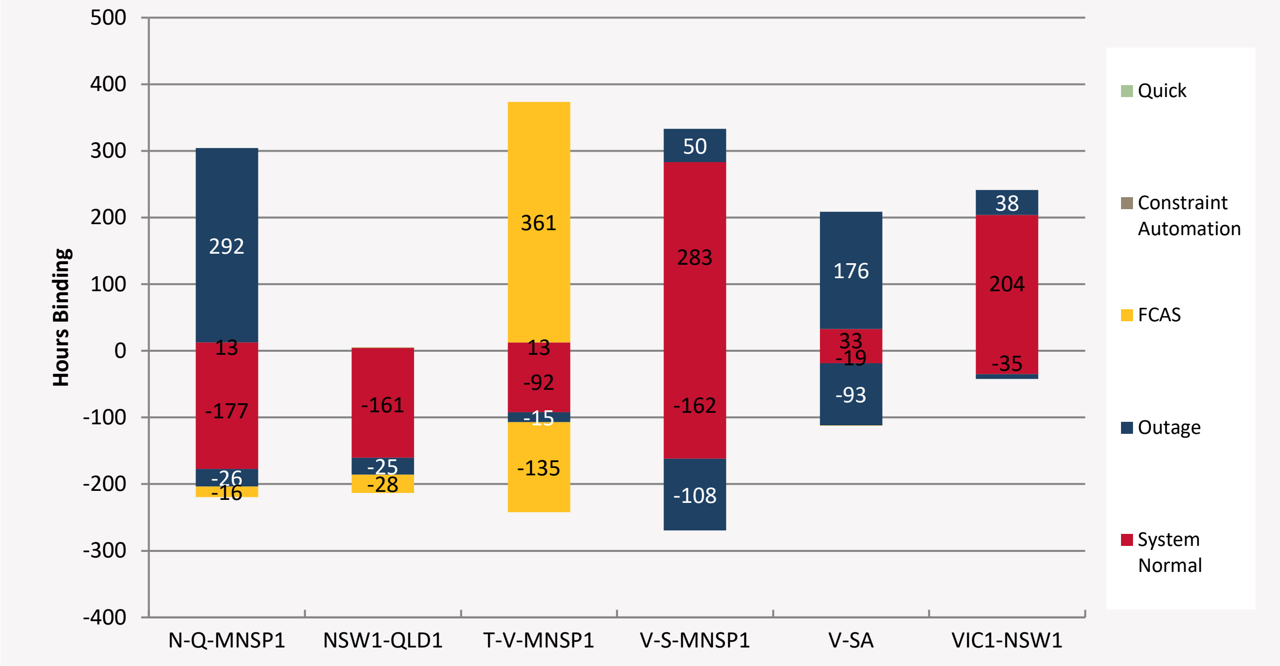
Non-real time constraint automation was not used.

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.

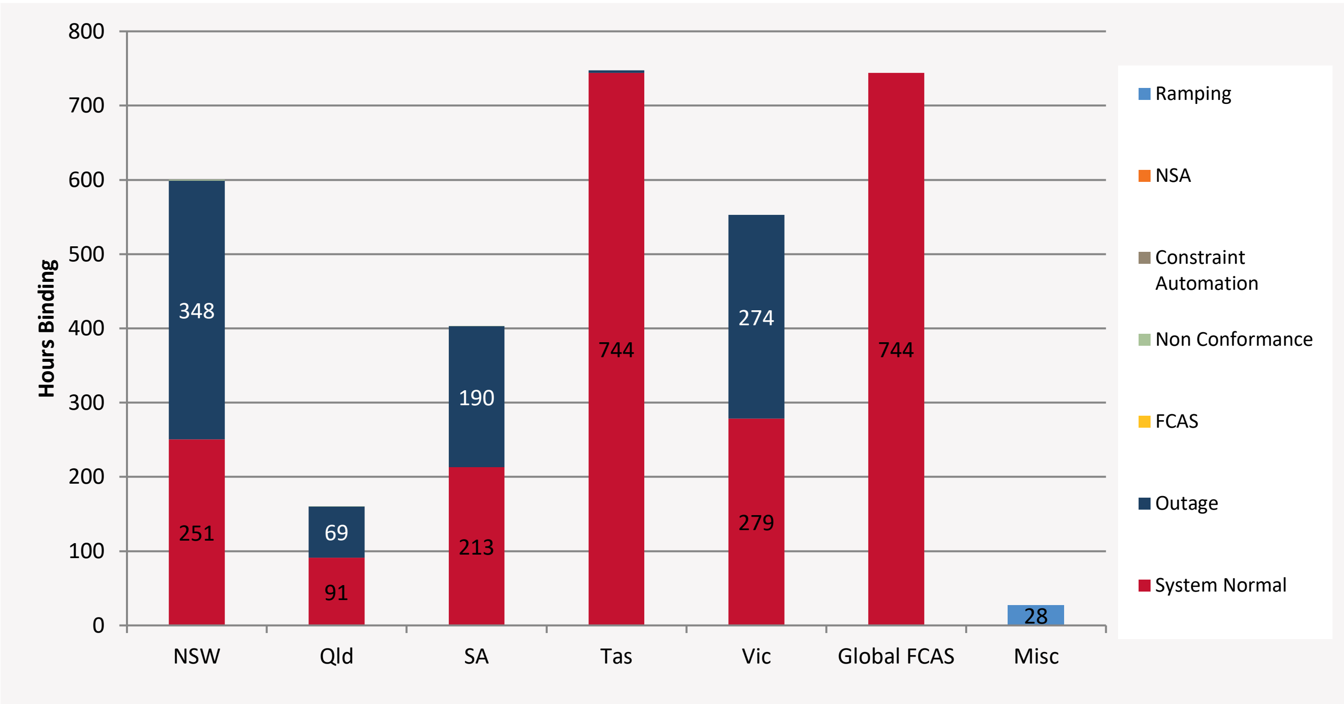
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

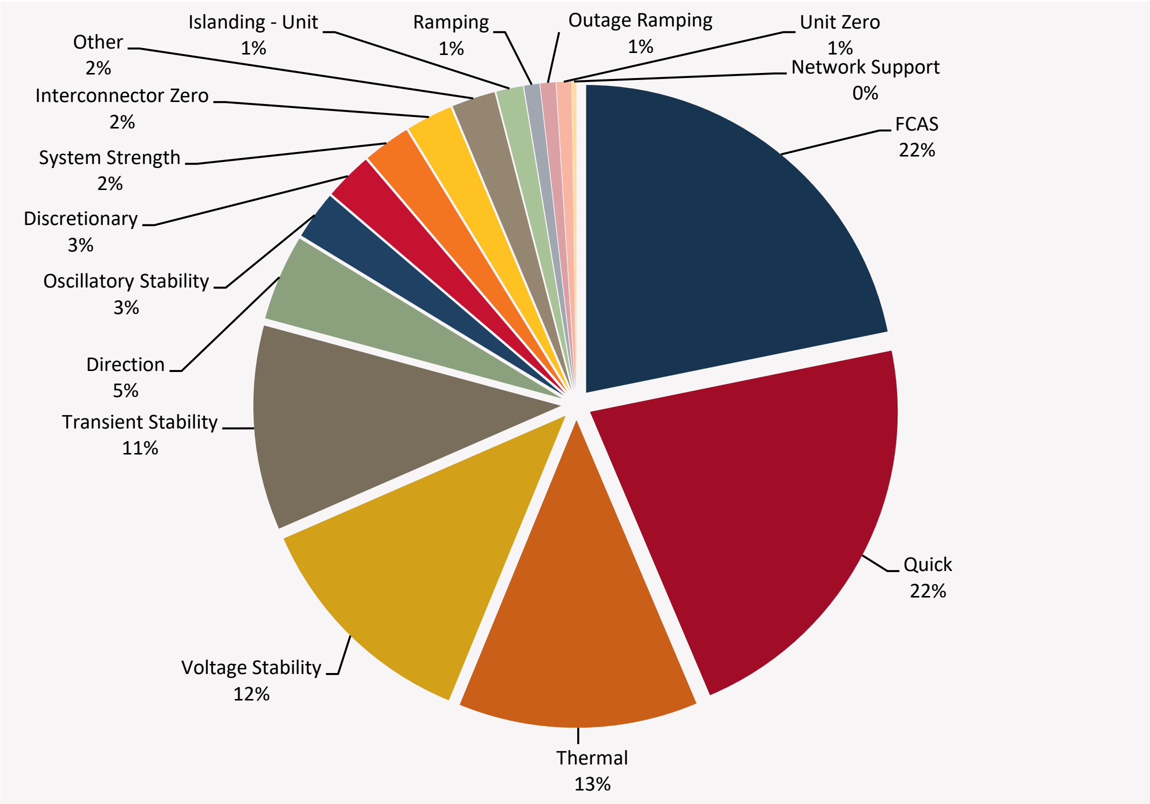
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

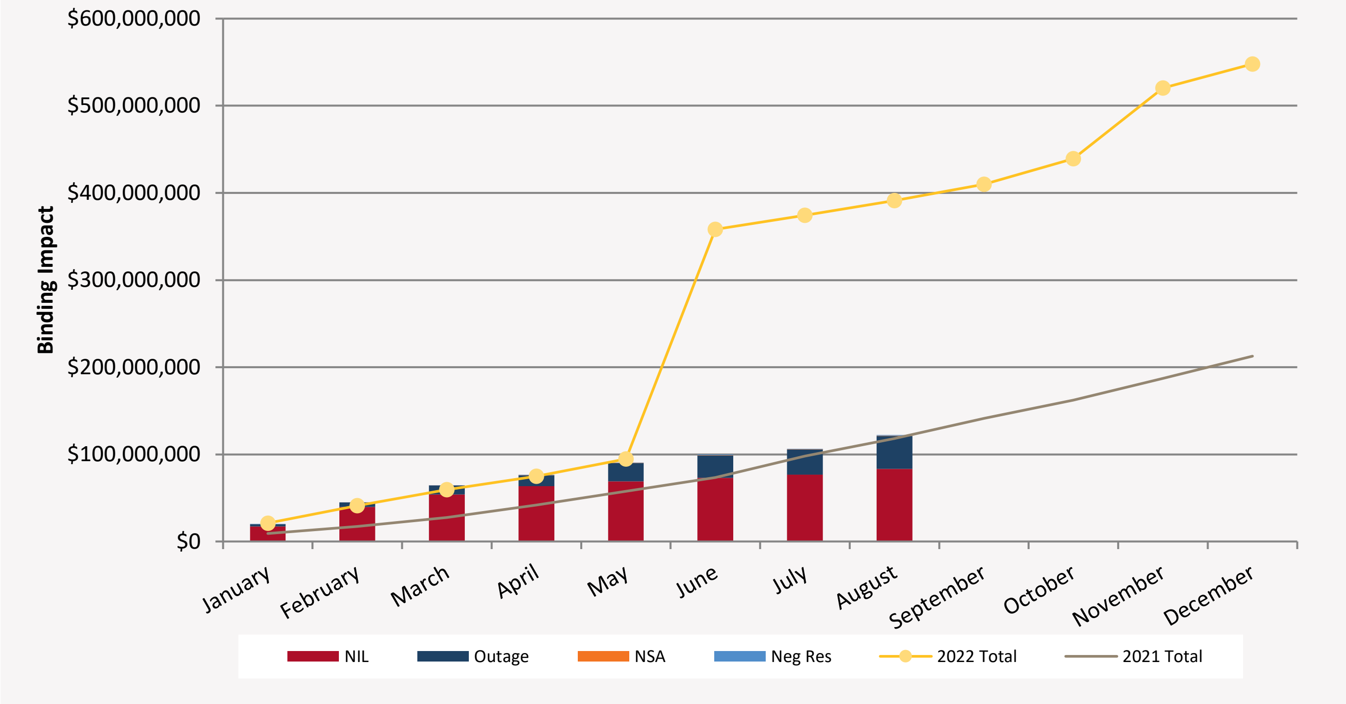
Figure 3 Binding by limit type



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
S^^V_SETB_1	Out= one South East to Tailem Bend 275kV line, voltage collapse equation Tailem Bend-Keith #2 132kV Line <=135 MW on trip of other Tailem Bend-South East 275kV line, Feedback (Note: with both SE series caps I/S or O/S)	132	9,742% (146.12)	210% (13.19)
V^SML_HORC_3	Out = Horsham to Murra Warra to Red Cliffs 220kV line OR Murra Warra to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	20	2,854% (72.35)	430% (38.97)
V^^SML_ARWBBA_1	Out = Ballarat to Waubra to Ararat 220kV line (or any line section between Ballarat and Ararat), avoid voltage collapse for loss of Bendigo to Kerang 220kV line	46	2,090% (89.3)	184% (32.77)
N>MPWW_94T_71	Out = Mt. Piper to Wallerawang (70 or 71), avoid O/L Molong to Orange North (94T) on trip of the remaining Mt Piper to Wallerawang (71 or 70), [Note: Line 94E O/S as per OM521]	10	565% (273.69)	272% (131.02)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_X_ARWBBA_V1	Out = Ararat to Waubra to Ballarat 220kV lines (complete circuit O/S), prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	5	335% (356.37)	154% (169.2)
V::N_X_ARWBBA_V2	Out = Ararat to Waubra to Ballarat 220kV lines (complete circuit O/S), prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	3	293% (467.94)	182% (359.5)
V>>DDTX2_DDTX3_DDTX1	Out= Dederang H2 txfmr, avoid O/L Dederang H3 330/220kV txfmr on trip of Dederang H1 330/220kV txfmr, Feedback	5	268% (179.08)	117.05% (57.74)
V::N_DDSM_V1	Out = Dederang to South Morang 330kV line, prevent transient instability for fault and trip of the parallel Dederang to South Morang 330kV line, VIC accelerates, Yallourn W G1 on 220 kV.	15	228% (182.82)	72.62% (70.74)
S::V_TBSE_TBSE	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps I/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	14	176% (16.54)	49.73% (5.8)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

S^^V_SETB_1: Investigated and no improvement can be made to the constraint equation at this stage.

V^^SML_ARWBBA_1: Investigated and no improvement can be made to the constraint equation at this stage.

N>MPWW_94T_71: Investigated and no improvement can be made to the constraint equation at this stage.

V>>DDTX2_DDTX3_DDTX1: Investigated and no improvement can be made to the constraint equation at this stage.

V^SML_HORC_3: 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.

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 August 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Flyers Creek Wind Farm	8 August 2023	NSW	New Generator
Rye Park Wind Farm	15 August 2023	NSW	New Generator
Mudgeeraba No.3 275kV/110kV Transformer	21 August 2023	QLD	Transformer de-commissioned
Tarrone Terminal Station K2 500kV/132kV Transformer	24 August 2023	VIC	Transformer commissioned for Tarrone Terminal Station

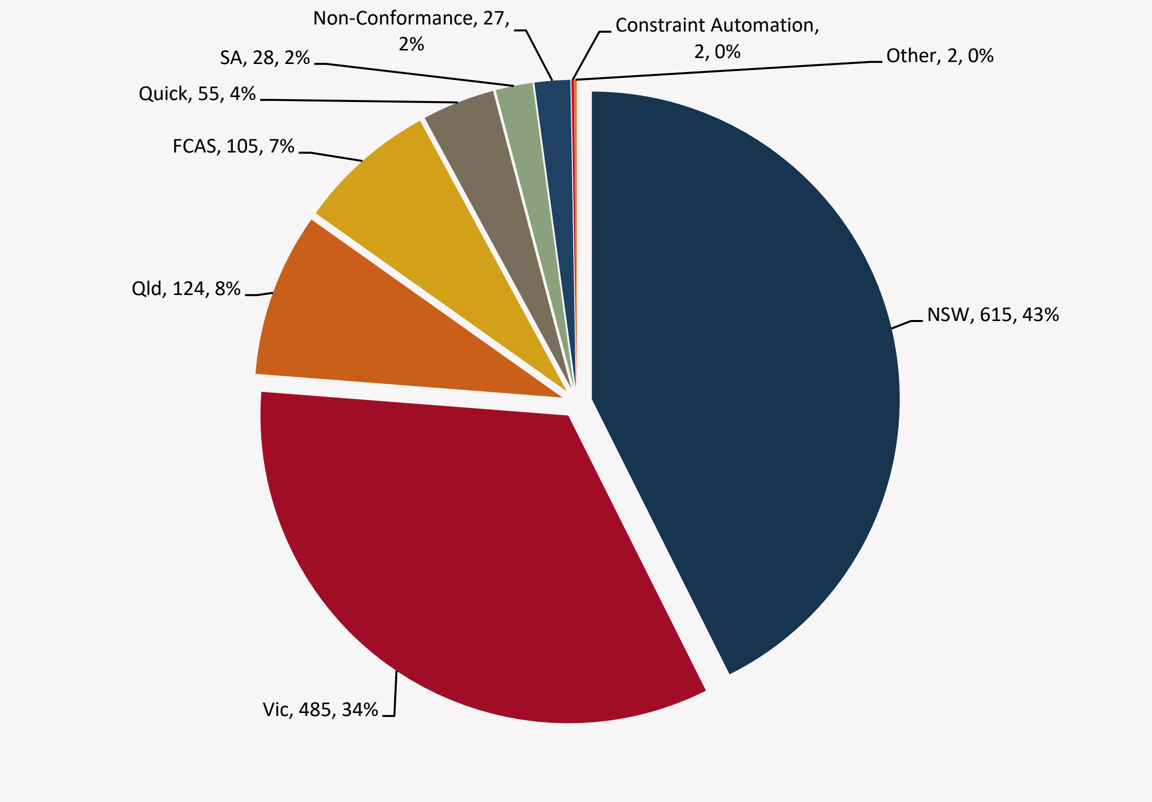
3.1 Constraint Equation Changes

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