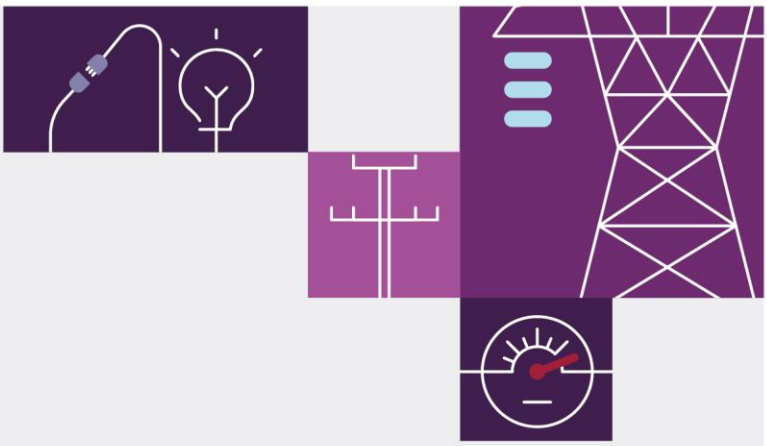
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

July 2024

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 July 2024. 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
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	1853 (154.41)	Interconnector Zero
Q_STR_7C0K_HASF_2	No limit to Haughton Solar Farm if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7, NQLD>250&270(AVG),Ross_FN>100&120(AVG),Haughton Syncon is ON, Zero otherwise.	1286 (107.16)	System Strength
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	1219 (101.58)	Voltage Stability
N>>NIL_964_84_S	Out= NIL, avoid O/L Port Macquarie to Herron Creek Tee (964/2) on trip of Tamworth to Liddell (84) line, Feedback	1036 (86.33)	Thermal
N^^V_MLNK_1	Out = Murraylink, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	855 (71.25)	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	850 (70.83)	Thermal
V>>NIL_ELML_BAML2	Out= Nil, avoid O/L Elaine to Moorabool 220kV line on trip of Ballarat to Moorabool No.2 220kV line, Feedback	785 (65.41)	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	671 (55.91)	Thermal
V_VS_LB_HY_50	Limit SA contingency size to 50 MW by limiting Heywood VIC to SA + Lake Bonney WF <= 50 MW when SA is at risk of separation. Constraint swamp out when Lake Bonney tripping scheme is O/S	606 (50.5)	System Strength
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	586 (48.83)	Voltage Stability

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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
Q_DAYDSF1_ZERO	Daydream solar farm upper limit of 0 MW	1,319,590	Unit Zero
N>NIL_BHTX_SF_TTS_HV	Out= NIL with one Broken Hill 220/22kV TX O/S (Note: only one TX can be I/S for system normal), avoid O/L remaining Broken Hill 220/22kV TX for contingency transfer tripping Broken Hill SF, (Note: Swamped when both TX1&2 I/S, Assumed 22kV CB 2112 I/S), FB	1,121,116	Thermal
Q_HAYMSF1_ZERO	Hayman solar farm upper limit of 0 MW	801,065	Unit Zero
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	694,038	Thermal
V^^V_MLNK_KGTS	Out= Murraylink, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line	599,468	Voltage Stability
V_VS_LB_HY_50	Limit SA contingency size to 50 MW by limiting Heywood VIC to SA + Lake Bonney WF <= 50 MW when SA is at risk of separation. Constraint swamp out when Lake Bonney tripping scheme is O/S	577,202	System Strength
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	566,856	Thermal
Q_STR_7C0K_MEWF_3	Limit Mt Emerald WF 80% if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad)>=7,Kar>=2, NQLD>350&370(AVG),Ross_FN>150&170(AVG), no limit if Haughton syncon ON or night,40% if Kar < 2 ,40% if NQLD>250,Ross_FN>100 or 25% if Syncon OFF or Kareeya <2. 0 otherwise	529,838	System Strength
V>>NIL_ELML_BAML2	Out= Nil, avoid O/L Elaine to Moorabool 220kV line on trip of Ballarat to Moorabool No.2 220kV line, Feedback	363,962	Thermal
VS_050_DYN	VIC to SA on Heywood upper transfer limit of 50 MW,dynamic headroom, DS formulation only.	346,233	Oscillatory Stability

[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.

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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 0.

Table 3 Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
Q_STR_8C_7C2K_RGUSF	No limit to Rugby Run SF to if Stan>=3+Cal>=1+Glad>=2+ (Stan+Cal+Glad)>=8+ one SVC(Dysart/ Nebo/Strathmore)OS OR Stan>=2+Cal>=1+Glad>=2+(Stan+Cal+Glad)>=7+Kar>=2+Dysart SVC OS/Haughton Syncon ON,NQLD>350&370(AVG),Ross_FN>150&170(AVG), Zero otherwise	15 (1.25)	System Strength
NRM_VIC1_NSW1	Negative Residue Management constraint for VIC to NSW flow	7 (0.58)	Negative Residue
V_BULBESS_0INV	Bulgana battery inverter limit of zero. Constraint to violate if Bulgana battery inverter availability greater than zero. Swamp out otherwise. DS only	4 (0.33)	System Strength
N>NIL_BHTX_SF_TTS_HV	Out= NIL with one Broken Hill 220/22kV TX O/S (Note: only one TX can be I/S for system normal), avoid O/L remaining Broken Hill 220/22kV TX for contingency transfer tripping Broken Hill SF, (Note: Swamped when both TX1&2 I/S, Assumed 22kV CB 2112 I/S), FB	3 (0.25)	Thermal
N_SUNRSF1_0INV	Sunraysia Solar Farm inverter limit of zero. Constraint to violate if Sunraysia Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	3 (0.25)	System Strength
N_DPESS_0INV	Darlington Point Battery inverter limit of zero. Constraint to violate if Darlington Point Battery inverter availability greater than zero. Swamp out otherwise. DS only	2 (0.16)	System Strength
F_T+NIL_MG_RECL_R60	Out = Nil, Raise 60 sec requirement for a Tasmania Reclassified Woolnorth Generation Event, Basslink unable to transfer FCAS	1 (0.08)	FCAS
N_BROKENH1_0INV	Broken Hill Solar Farm inverter limit of zero. Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	1 (0.08)	System Strength
N_LIMOSF1_0INV	Limondale 1 Solar Farm inverter limit of zero. Constraint to violate if Limondale 1 Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	1 (0.08)	System Strength
N_RESS1_0INV	Riverina 1 Battery inverter limit of zero. Constraint to violate if Riverina 1 Battery inverter availability greater than zero. Swamp out otherwise. DS only	1 (0.08)	System Strength

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2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
Q_STR_8C_7C2K_RGUSF	Constraint equation violated for 15 consecutive DIs between 24/07/2024 0705 hrs and 24/07/2024 0815 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Rugby Run Solar Farm exceeding its MVAr limit.
NRM_VIC1_NSW1	Constraint equation violated for 7 non-consecutive Dis between 25/07/2024 1015 hrs and 25/07/2024 1050 hrs with a max violation degree of 229.05 MW occurring on 25/07/2024 1020 hrs. Constraint equation violated due to competing requirement on the export limits of VNI set by N^^V_MSDD2 and N::V_DDMS.
V_BULBESS_0INV	Constraint equation violated for 4 non-consecutive DIs between 10/07/2024 0605 hrs and 11/07/2024 0615 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Bulgana BESS exceeding its inverter limit.
N>NIL_BHTX_SF_TTS_HV	Constraint equation violated for 3 consecutive DIs on 03/07/2024 1220 hrs, 1225 hrs and 1230 hrs with a max violation degree of 0.4 MW on 03/07/2024 1230 hrs. Constraint equation violated due to constraint formulation error. The constraint was blocked and has since been corrected.
N_SUNRSF1_0INV	Constraint equation violated for 3 consecutive DIs between 23/07/2024 0735 hrs and 23/07/2024 0745 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Sunraysia Solar Farm inverter availability exceeding its limit.
N_DPESS_0INV	Constraint equation violated for 2 consecutive DIs between 23/07/2024 1805 hrs and 23/07/2024 1810 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Darlington Point Battery inverter availability exceeding its limit.
F_T+NIL_MG_RECL_R60	Constraint equation violated for 1 DI on 01/07/2024 0825 hrs with a violation degree of 1.41 MW. Constraint equation violated due Tasmania raise 60 second service availability being less than the requirement.
N_BROKENH1_0INV	Constraint equation violated for 1 DI on 23/07/2024 0735 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Broken Hill Solar Farm inverter availability exceeding its limit.
N_LIMOSF1_0INV	Constraint equation violated for 1 DI on 23/07/2024 1850 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Limondale 1 Solar Farm inverter availability exceeding its limit.
N_RESS1_0INV	Constraint equation violated for 1 DI on 23/07/2024 1810 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Riverina 1 Battery inverter availability exceeding its limit.

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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)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	1611 (134.25)	0.0 (0.0)
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	1252 (104.33)	-445.99 (-478.0)
N^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	1217 (101.42)	-298.86 (-817.05)
N^^V_NIL_1	V-S-MNSP1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	1049 (87.42)	56.56 (-149.8)
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	990 (82.5)	50.28 (-156.34)
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	961 (80.08)	-863.99 (-1200.01)
N^^V_MLNK_1	VIC1-NSW1 Import	Out = Murraylink, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	853 (71.08)	-258.77 (-951.69)
F_MAIN++APD_TL_L60	T-V-MNSP1 Import	Out = Nil, Lower 60 sec 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	801 (66.75)	-435.53 (-478.0)
V>>NIL_ELML_BAML2	VIC1-NSW1 Import	Out= Nil, avoid O/L Elaine to Moorabool 220kV line on trip of Ballarat to Moorabool No.2 220kV line, Feedback	764 (63.67)	719.91 (-384.4)
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	763 (63.58)	159.98 (180.69)

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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_559DA1A7	08/07/2024 08:30 to 08/07/2024 11:05	CA_SYDS_559DA1A7 was built to manage the overloading of Tenterfield – Casino 132 kV 96L/1 Line for the loss of Lismore – Koolkhan 132kV 967 Line with prior outage of Coffs – Lismore 330kV 89 Line.

2.5.1 Further Investigation

CA_SYDS_559DA1A7: The constraint automation equation was invoked but did not bind. CA_SYDS_559DA1A7 allowed for increased southernly flows on Directlink.CA_SYDS_559DA1A7 was revoked at 1105 hrs and the existing constraint equation N>89_96R_967 was updated to better manage future violation issues.

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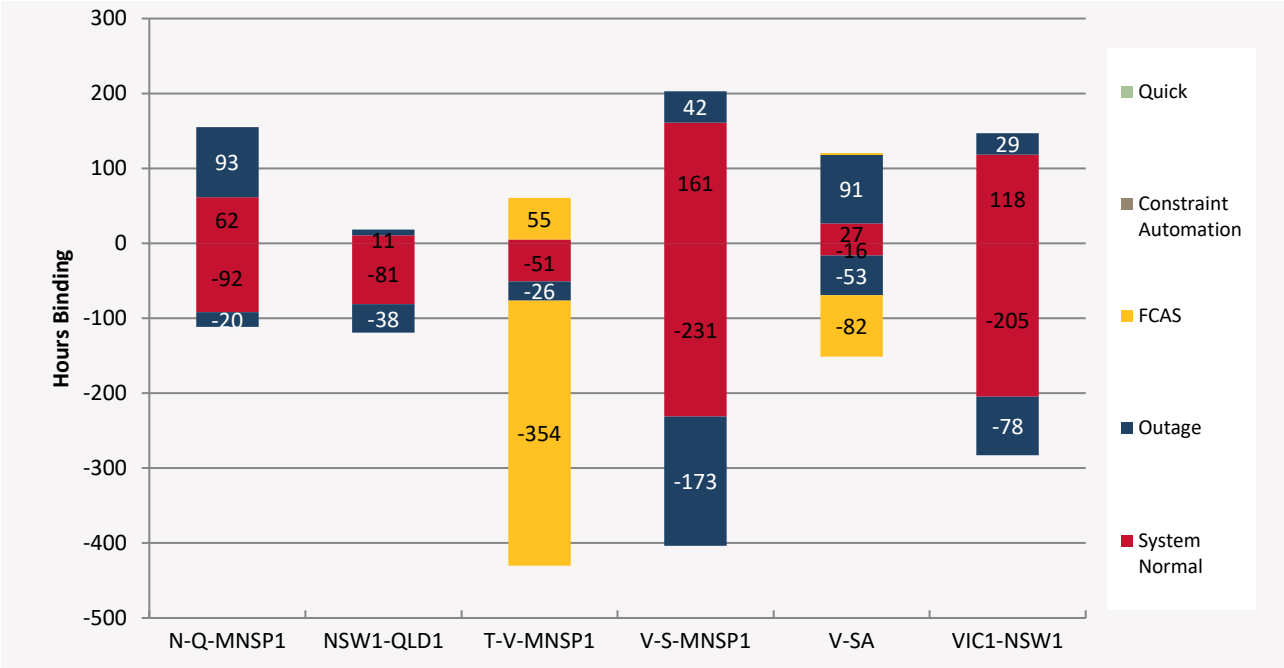
2.6 Binding Dispatch Hours

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.

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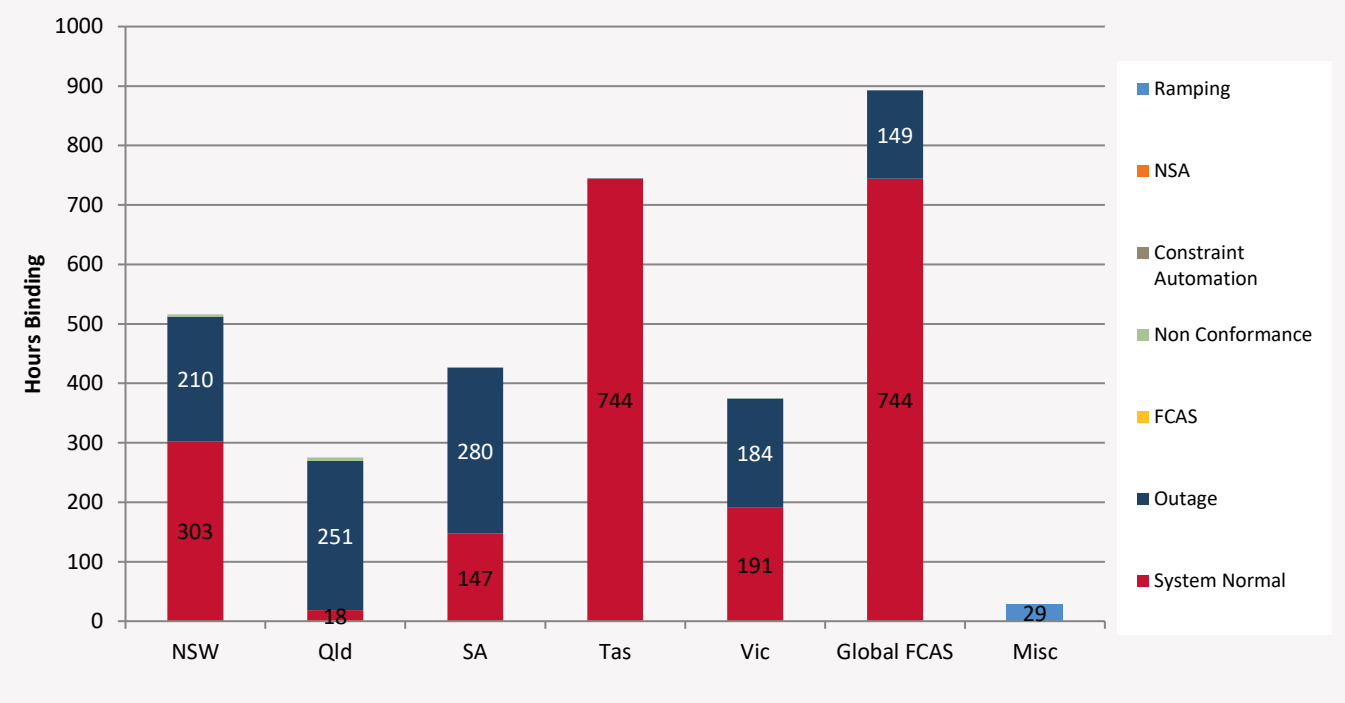
Figure 2 Regional binding dispatch hours



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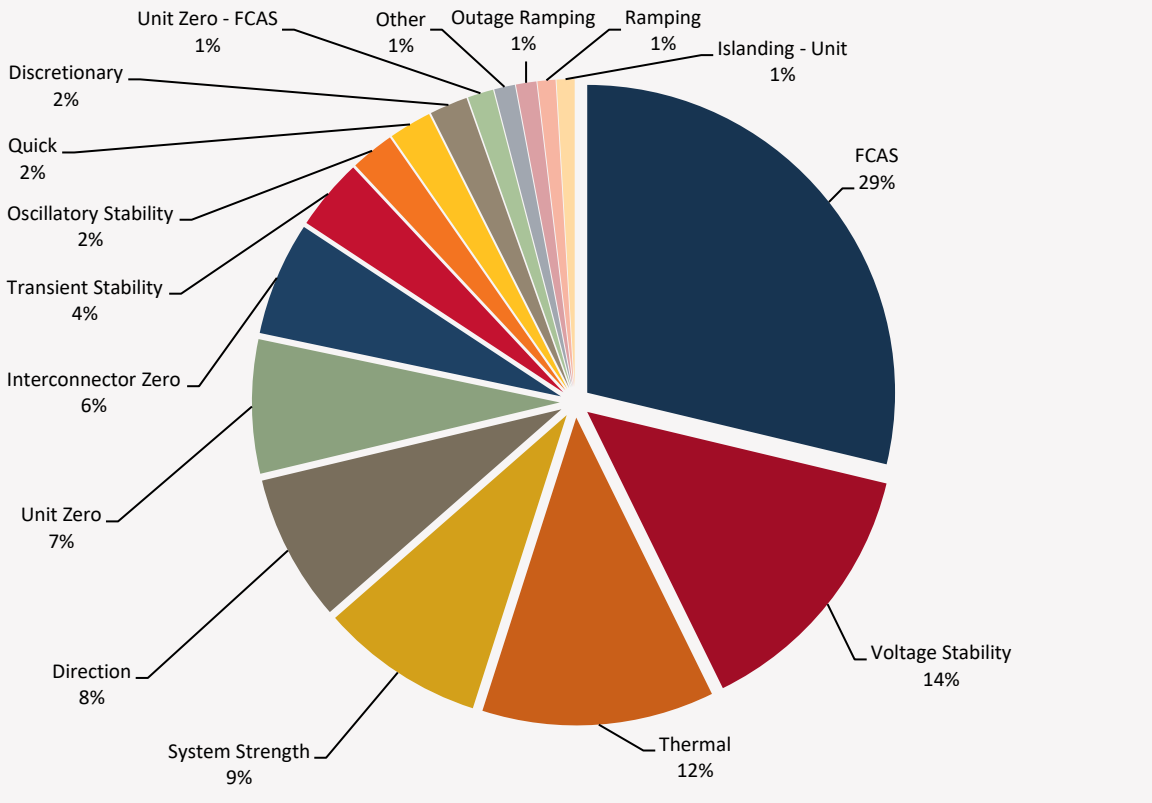
2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals for July 2024 that the different types of constraint equations bound.

Figure 3 Binding by limit type



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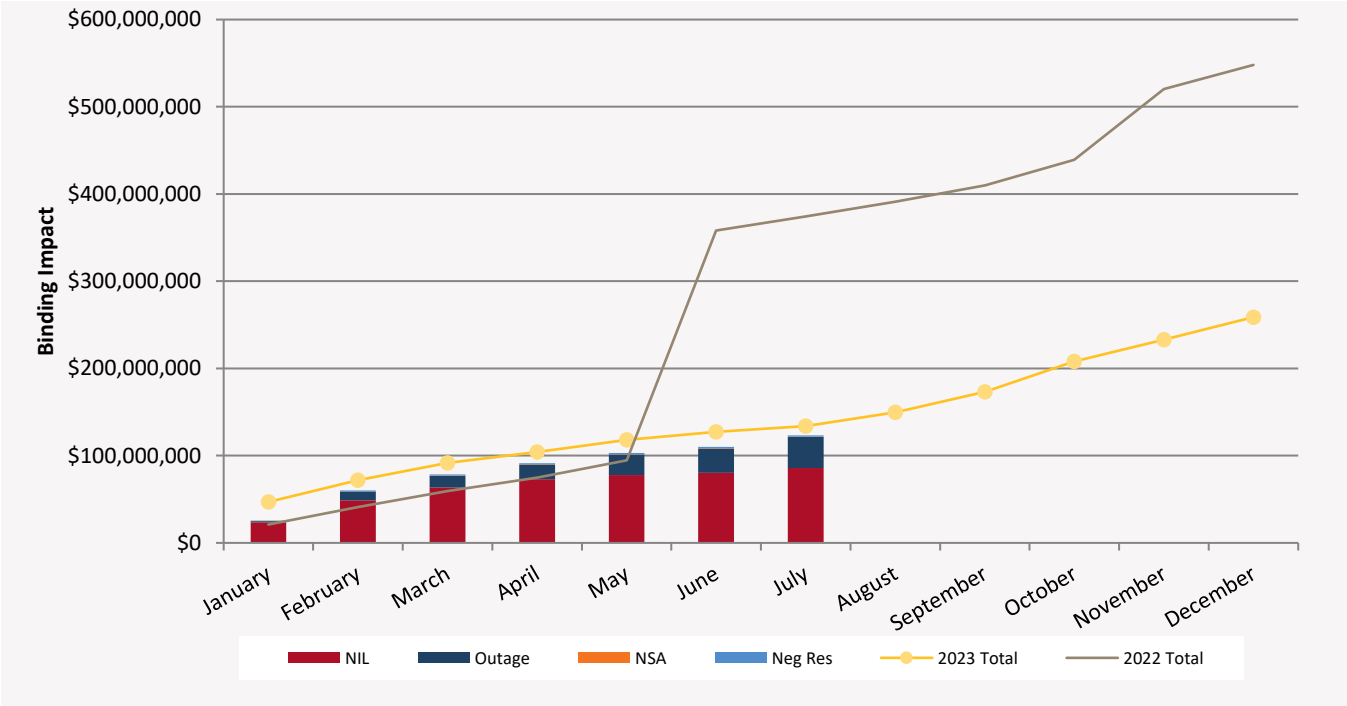
2.8 Binding Impact Comparison

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



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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
N>89_96R_967	Out= Coffs Harbour to Lismore (89), avoid O/L Glen Innes to Tenterfield (96R) on trip of Koolkhan to Lismore (967), (NOTE: swamp out when all 3 directlink O/S)	39	4,061% (132.92)	491% (58.82)
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.	15	2,127% (246.86)	260% (137.16)
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.	41	1,923% (244.15)	124.56% (81.41)
S>>V_CGTI_TIPA_PGPA	Out= Cherry Gardens - Torrens Island 275kV line, avoid O/L Parafield Gardens West-Para 275kV line on trip of Torrens Island A -Para 275kV line, Feedback	3	636% (291.7)	323% (282.34)
V::N_HYSE_V1	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 220 kV.	52	598% (266.07)	60.21% (75.96)
S_ISLE_CRK_60	Discretionary upper limit on Cathedral Rocks windfarm <=60 MW when 4 syn cons I/S for SA is at risk of islanding - otherwise limited to 10 MW	4	500% (50.)	500% (50.)
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.	82	478% (267.7)	62.25% (77.63)
N::V_DDMS	Out=Dederang to Murray (67 or 68) line, NSW to Victoria Transient stability limit.	8	342% (965)	137.88% (483.19)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	52	260% (12.3)	54.21% (3.73)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N>89_96R_967: Investigated and no improvement can be made to the constraint – this issue is mainly due to Directlink being out of service during the outage.

V::N_HYSE_V1: 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.

T^T_NIL_BL_6: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_NIL_V1: Investigated and no improvement can be made to the constraint equation at this stage.

N::V_DDMS: 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.

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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 July 2024.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Broken Hill Battery BDU	4 July 2024	NSW	Existing battery changed to BDU
Wandoan South Battery BDU	4 July 2024	QLD	Existing battery changed to BDU
Dalrymple Nth Battery BDU	12 July 2024	SA	Existing battery changed to BDU
Torrens Island Battery BDU	12 July 2024	SA	Existing battery changed to BDU
Girgarre Solar Farm	16 July 2024	VIC	New Generator
Riverina 2 Battery BDU	18 July 2024	NSW	Existing battery changed to BDU
Darlington Point Battery BDU	18 July 2024	NSW	Existing battery changed to BDU
Ballarat Battery BDU	18 July 2024	VIC	Existing battery changed to BDU
Gannawarra Battery BDU	18 July 2024	VIC	Existing battery changed to BDU
Cressy Terminal Station Cut-in	18 July 2024	VIC	Cressy Terminal Station has been cut into the existing Moorabool – Haunted Gully No.1 500 kV Line to form the following circuits: Cressy – Haunted Gully No.1 500 kV Line. Cressy – Moorabool No.1 500 kV Line
Wandoan South Bess (Load Component)	26 July 2024	QLD	Deregistered generator due to BDU cut over.
Broken Hill Battery 50 MW (Gen Mode)	26 July 2024	NSW	Deregistered generator due to BDU cut over.
Wandoan South Bess (Generation Component)	26 July 2024	QLD	Deregistered generator due to BDU cut over.
Broken Hill Battery 50 MW (Load Mode)	26 July 2024	NSW	Deregistered generator due to BDU cut over.
Ryan Corner Wind Farm	30 July 2024	VIC	New Generator
Cressy Terminal Station	30 July 2024	VIC	Cressy Terminal Station was cut into existing Moorabool – Mortlake No.2 500 kV line to from the following circuits: Cressy – Mortlake No.2 500 kV Line Cressy – Moorabool No.2 500 kV Line
Dalrymple Battery (Load Component)	31 July 2024	SA	Deregistered generator due to BDU cut over.
Torrens Island Battery (Load Mode) MW	31 July 2024	SA	Deregistered generator due to BDU cut over.
Torrens Island Battery (Generation Mode)	31 July 2024	SA	Deregistered generator due to BDU cut over.
Dalrymple Battery (Generation Component)	31 July 2024	SA	Deregistered generator due to BDU cut over.

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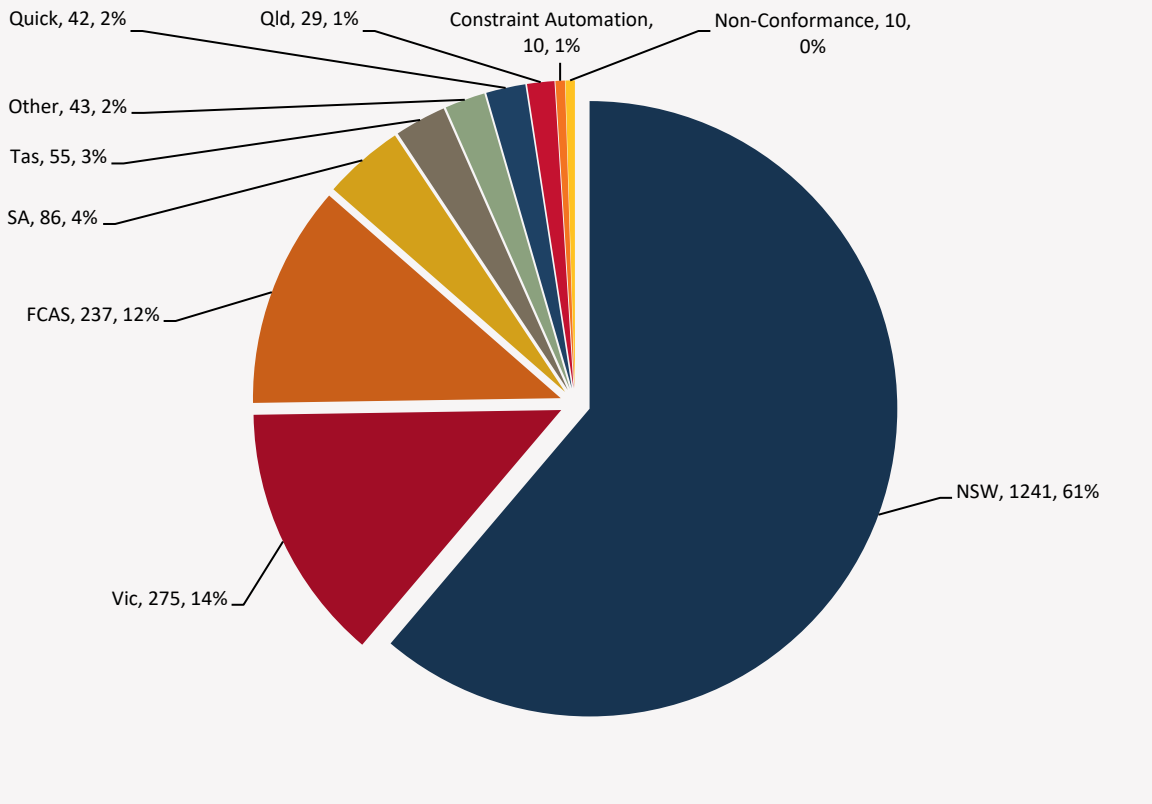
3.1 Constraint Equation Changes

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].

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.

[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

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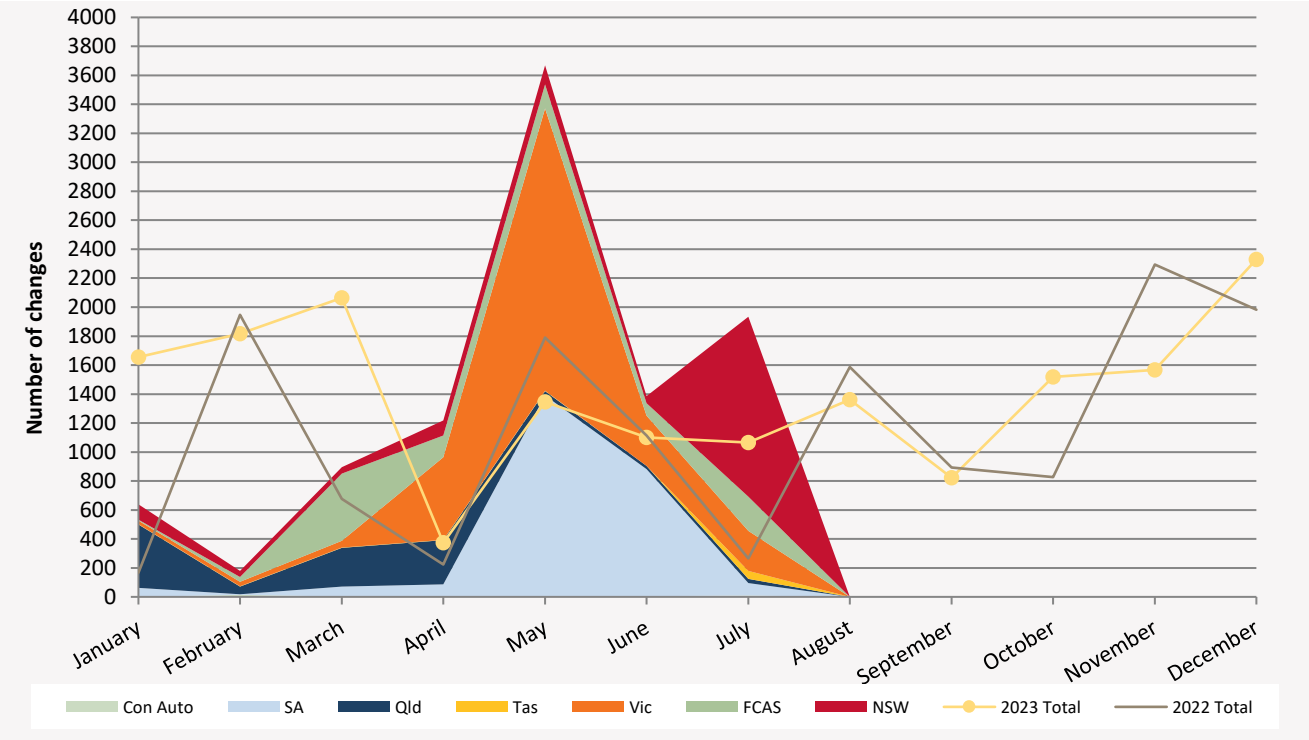
Figure 6 Constraint equation changes per month compared to previous two years



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