AEMO

AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

April 2022

A report for the National Electricity Market on Constraint results.

Important notice

Purpose

This publication has been prepared by AEMO to provide information about constraint equation performance and related issues, as at the date of publication.

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1 Introduction

This report details constraint equation performance and transmission congestion related issues for April 2022. 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 in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; Swamp out when three directlink cables are O/S; TG formulation only	5425 (452.08)	Voltage Stability
Q_STR_7C2K_HASF_4	No limit to Haughton Solar Farm if Stan>=2+Cal>=1+Glad>=2+(Stan+Cal+Glad) >=7+Kar>=2,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON, Zero otherwise.	4350 (362.5)	System Strength
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1741 (145.08)	Thermal
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	1641 (136.75)	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	1388 (115.66)	Voltage Stability
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1371 (114.25)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1287 (107.25)	Thermal
N>>N-NIL_94K_1	Out= Nil, avoid O/L on Wellington Suntop Tee to Wellington 94K/1 132kV line on trip of Nil, Feedback	1185 (98.75)	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge (733/1 and 734/1), Feedback	1034 (86.16)	Thermal
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.	996 (83.0)	Transient Stability

2.2 Top 10 binding impact constraint equations

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

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

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

Table 2 Top 10 binding impact network constraint equations

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Limit Type
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2,244,030	Thermal
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1,461,914	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1,340,012	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	1,222,299	Voltage Stability
N>>N-NIL_94K_1	Out= Nil, avoid O/L on Wellington Suntop Tee to Wellington 94K/1 132kV line on trip of Nil, Feedback	1,045,054	Thermal
Q_STR_7C2K_MEWF_3	No limit to Mt Emerald Windfarm if Stan>=2+Cal>=1+Glad>=2+ (Stan+Cal+Glad) >=7+Kar>=2,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON (80% if Haughton Syncon is OFF), Zero otherwise.	951,377	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	929,879	Thermal
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	393,626	Voltage Stability
N^N-LS_SVC	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; Swamp out when three directlink cables are O/S; TG formulation only	381,628	Voltage Stability
N>N-NIL_997_99A	Out= Nil, avoid O/L Corowa to Albury 132kV line (997/1) on trip of Finley to Uranquinty 132kV line (99A), Feedback	345,446	Thermal

2.3 Top 10 violating constraint equations

A constraint equation is violating when NEMDE is unable to dispatch the entities on the left-hand side (LHS) so the summated LHS value is less than or equal to, or greater than or equal to, the right-hand side (RHS) value

[1] The MCC re-run relaxes any violating constraint equations and constraint equations with a marginal value equal to the constraint equation's violation penalty factor (CVP) x market price cap (MPC). The calculation caps the marginal value in each DI at the MPC value valid on that date. MPC is increased annually on 1st July.

(depending on the mathematical operator selected for the constraint equation). The following table includes the FCAS constraint equations. Reasons for the violations are covered in 2.3.1.

Table 3 Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	8 (0.66)	Negative Residue
V_KIAMSF_40INV	Limit Kiamal Solar Farm upper limit to 0 MW if number of inverter available exceeds 40. Constraint swamps out otherwise. DS only	5 (0.41)	System Strength
Q-MEWF_MVAR	Constraint to violate if Reactive power output of Mt Emerald Wind farm Solar farm is greater than +/10Mvar when it is limited at 0MW output, Swamp if MW >0 (DS only)	4 (0.33)	Unit Zero
Q-X_STR_7C8C_RRSF	Out=One or more 275KV Fdrs in NQLD, limit Ross River Solar farm output depends on the number units online in Stanwell, Callide, Gladstone and Kareeya generators, Haughton Syncon and NQLD demand, Zero if it does not meet minimum requirement	4 (0.33)	System Strength
Q_STR_7C2K_RRSF_3	No limit to Ross River Solar Farm if Stan>=2+Cal>=1+Glad>=2+ (Stan+Cal+Glad) >=7+Kar>=2,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON (80% if Haughton Syncon is OFF),Zero otherwise.	4 (0.33)	System Strength
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	3 (0.25)	FCAS
Q-X_STR_7C8C_RUGSF	Out=One or more 275KV Fdrs in NQLD, limit Rugby Run Solar farm output depends on the number units online in Stanwell, Callide, Gladstone and Kareeya generators, Haughton Syncon and NQLD demand, Zero if it does not meet minimum requirement	3 (0.25)	System Strength
Q-X_STR_7C8C_SMSF	Out=One or more 275KV Fdrs in NQLD, limit Sun Metals Solar farm output depends on the number units online in Stanwell, Callide, Gladstone and Kareeya generators, Haughton Syncon and NQLD demand, Zero if it does not meet minimum requirement	3 (0.25)	System Strength
Q_STR_7C2K_RUGSF_3	No limit to Rugby Run Solar Farm if Stan>=2+Cal>=1+Glad>=2+ (Stan+Cal+Glad) >=7+Kar>=2,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON (80% if Haughton Syncon is OFF),Zero otherwise.	3 (0.25)	System Strength
Q_STR_7C2K_SMSF_3	No limit to Sun Metals Solar Farm if Stan>=2+Cal>=1+Glad>=2+ (Stan+Cal+Glad) >=7+Kar>=2,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON (80% if Haughton Syncon is OFF),Zero otherwise.	3 (0.25)	System Strength

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
NRM_QLD1_NSW1	Constraint violated for 8 DIs on 05/04/2022 between 1735 hrs and 1825 hrs with a max violation of 68.34 MW occurring on 05/04/2022 at 1820 hrs. Constraint violated due to competing requirements with the export limits of QNI and Terranora interconnector which were set by constraint equations N^^Q_ARDM_B1 and N^N-LS_SVC.
V_KIAMSF_40INV	Constraint violated for 5 consecutive DIs on 05/04/2022 from 1035 hrs to 1055 hrs with violation degree of 0.001 MW. Constraint violated due to Kiamal Solar Farm exceeding its inverter limit.
Q-MEWF_MVAR	Constraint violated for 4 consecutive DIs on 30/04/2022 from 0715 hrs to 0730 hrs with a violation degree of 0.001 MW. Constraint violated due to Mt Emerald Wind Farm exceeding its MVAr limit.

Constraint Equation ID (System Normal Bold)	Description
Q-X_STR_7C8C_RRSF	Constraint violated for 4 consecutive DIs on 06/04/2022 from 0955 hrs to 1010 hrs with a violation degree of 0.001 MW. Constraint violated due to Ross River Solar Farm exceeding its MVAr limit.
Q_STR_7C2K_RRSF_3	Constraint violated for 4 consecutive DIs on 06/04/2022 from 0955 hrs to 1010 hrs with a violation degree of 0.001 MW. Constraint violated for the same reason as above.
F_T+RREG_0050	Constraint violated for 3 DIs on 14/04/2022 at 2305 hrs, on 17/04/2022 at 1635 hrs, and on 19/04/2022 at 0430 hrs with a max violation of 11.63 MW occurring on 19/04/2022 at 0430 hrs. Constraint violated due to the Tasmania raise Regulation availability being lower than the requirement.
Q-X_STR_7C8C_RUGSF	Constraint violated for 3 DIs on 06/04/2022 at 1000 hrs, 1005 hrs, and 1035 hrs, with a violation degree of 0.001 MW. Constraint violated due to Rugby Run Solar Farm exceeding its MVAr limit.
Q_STR_7C2K_RUGSF_3	Constraint violated for 3 DIs on 06/04/2022 at 1000 hrs, 1005 hrs, and 1035 hrs, with a violation degree of 0.001 MW. Constraint violated for the same reason as above.
Q-X_STR_7C8C_SMSF	Constraint violated for 3 DIs on 06/04/2022 from 1015 hrs to 1025 hrs with a violation degree of 0.001 MW. Constraint violated due to Sun Metal Solar Farm exceeding its MVAr limit.
Q_STR_7C2K_SMSF_3	Constraint violated for 3 DIs on 06/04/2022 from 1015 hrs to 1025 hrs with a violation degree of 0.001 MW. Constraint violated for the same reason as above.

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 in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; Swamp out when three directlink cables are O/S; TG formulation only	5078 (423.17)	-62.4 (47.52)
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	1473 (122.75)	152.22 (177.69)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1394 (116.17)	37.05 (439.01)
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	1151 (95.92)	222.51 (939.48)
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	1137 (94.75)	130.51 (-140.67)
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	963 (80.25)	-213.27 (-439.0)
V::N_DDSM_V1	V-SA Import	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.	928 (77.33)	-0.98 (-420.0)
V::N_DDSM_V1	T-V-MNSP1 Import	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.	894 (74.5)	-253.36 (-439.0)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	835 (69.58)	26.51 (439.01)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
V::N_DDSM_V1	V-S-MNSP1 Export	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.	807 (67.25)	-36.66 (173.95)

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

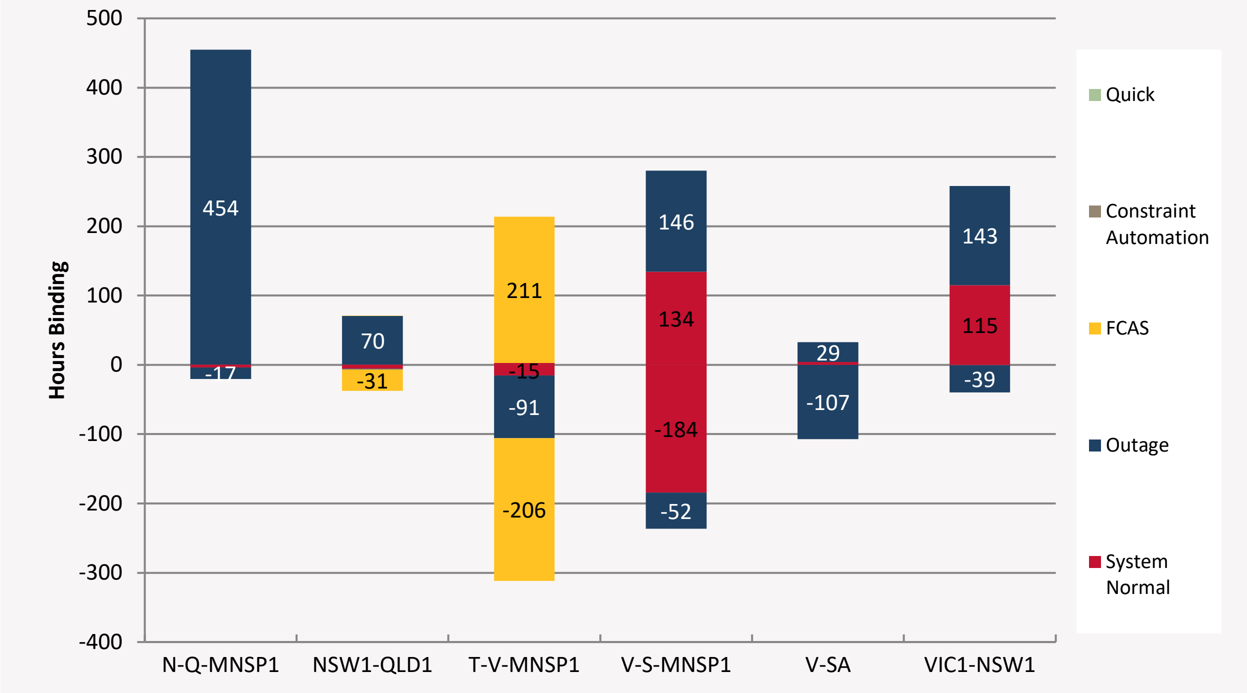
Non-real time constraint automation was not used.

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.

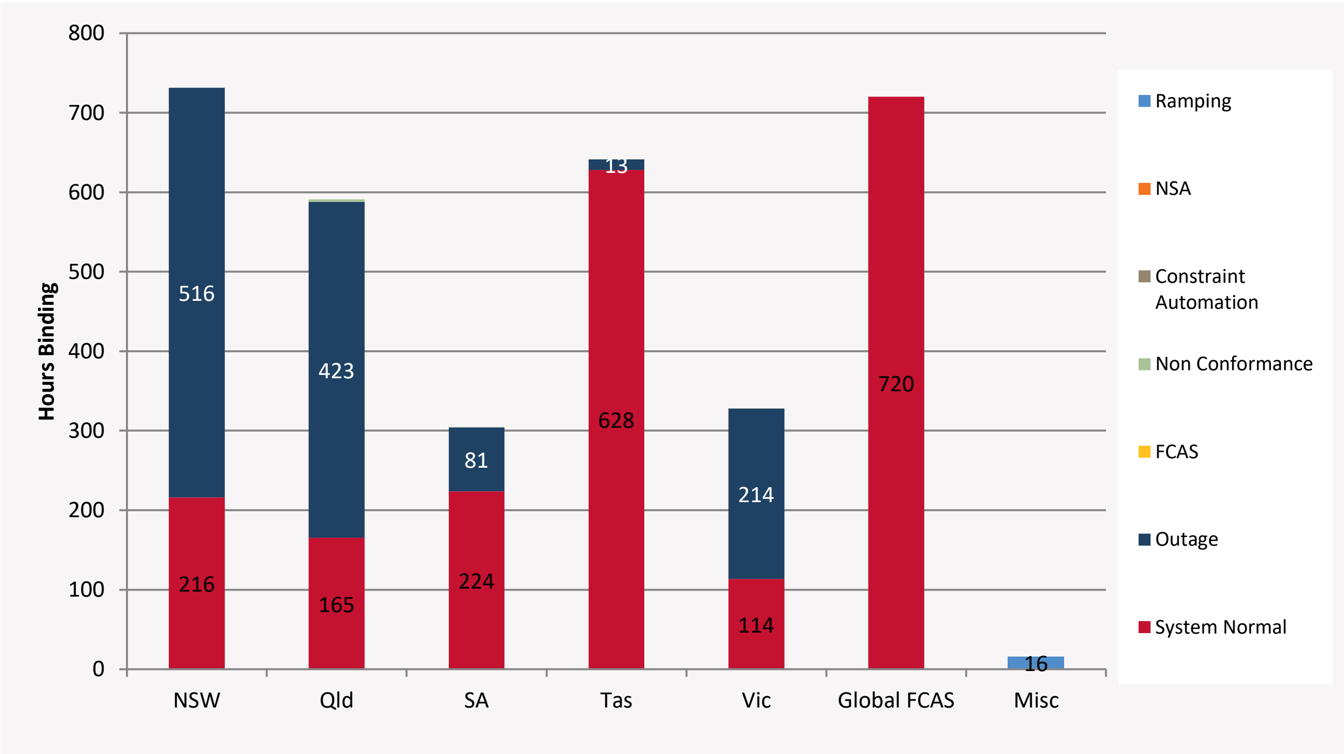
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

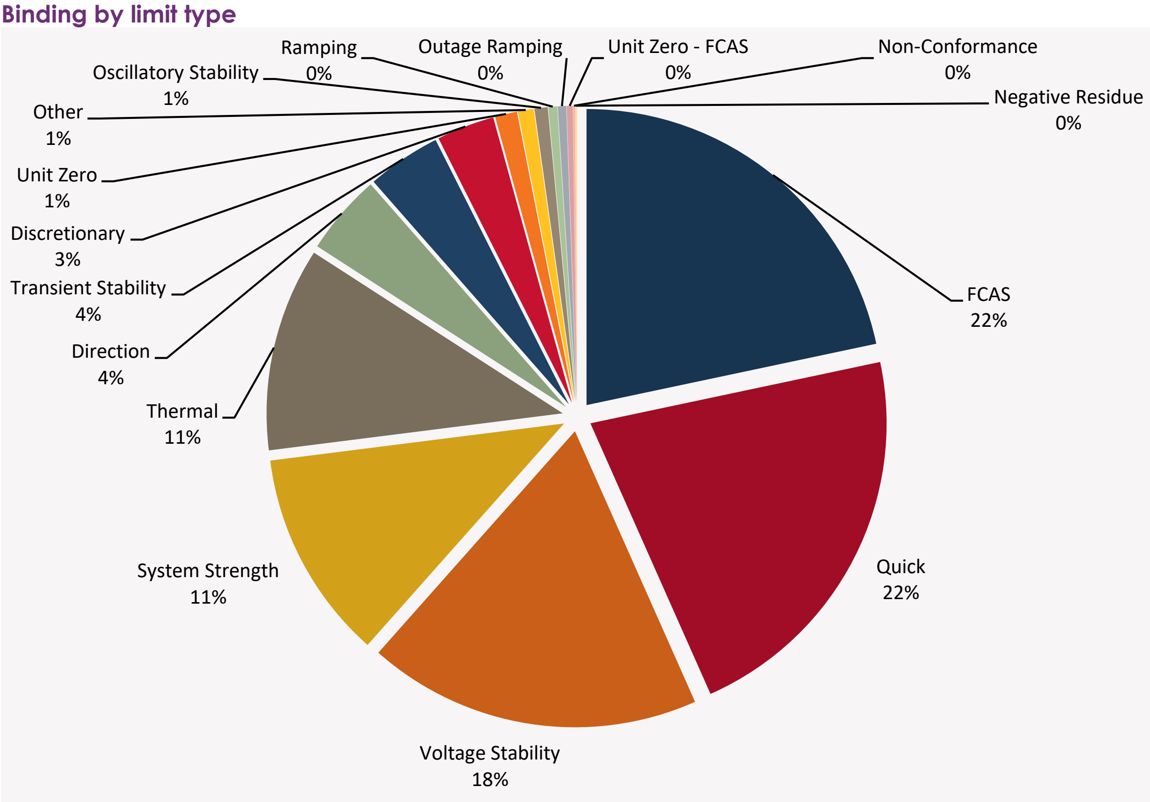
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals for April 2022 that the different types of constraint equations bound.

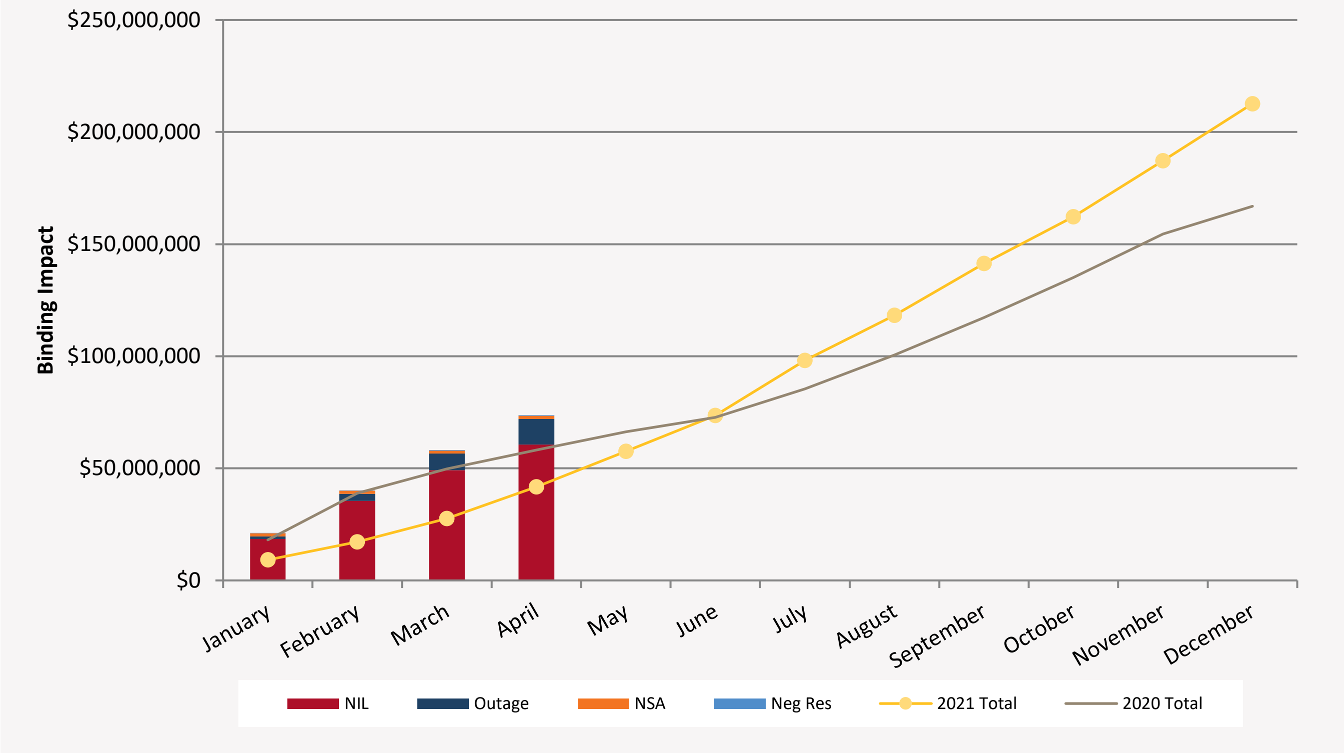
Figure 3 Binding by limit type



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
N^N-LS_SVC	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; Swamp out when three directlink cables are O/S; TG formulation only	980	7,517% (99.34)	88.9% (19.78)
V_S_HEYWOOD_UFLS	Out= Nil, Limit Heywood flows when SA under frequency load shedding (UFLS) is insufficient (i.e. when UFLS blocks in SA <1000 MW) to manage for double-circuit loss of Heywood IC. Note: Constraint is swamped if UFLS blocks >= 1000 MW.	27	1,732% (9,454)	443% (2,469)
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.	6	476% (258.83)	155% (110.19)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_X_SMSC_O2	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 500kV.	21	123.98% (437.08)	40.48% (150.33)
Q_STR_7C2K_MEWF_3	No limit to Mt Emerald Windfarm if Stan>=2+Cal>=1+Glad>=2+ (Stan+Cal+Glad) >=7+Kar>=2,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON (80% if Haughton Syncon is OFF),Zero otherwise.	104	100.% (144.)	4.8% (6.92)
V_MOORBWF_150_0SWT	Moorabool Wind Farm upper limit of 150 MW. Limit Moorabool wind farm to 0 MW if any turbine online from the Moorabool wind farm - South (Cluster 2)	21	100.% (150.)	61.9% (150.)
Q-X_STR_7C8C_HAYSF	Out=One or more 275KV Fdrs in NQLD, limit Hayman Solar farm output depends on the number units online in Stanwell, Callide, Gladstone and Kareeya generators, Haughton Syncon and NQLD demand, Zero if it does not meet minimum requirement	5	100.% (30.)	100.% (30.)
Q-X_STR_7C8C_DAYSF	Out=One or more 275KV Fdrs in NQLD, limit Daydream Solar farm output depends on the number units online in Stanwell, Callide, Gladstone and Kareeya generators, Haughton Syncon and NQLD demand, Zero if it does not meet minimum requirement	5	100.% (90.)	100.% (90.)
Q-X_STR_7C8C_MEWF	Out=One or more 275KV Fdrs in NQLD, limit Mt Emerald windfarm output depends on the number units online in Stanwell, Callide, Gladstone and Kareeya generators, Haughton Syncon and NQLD demand, Zero if it does not meet minimum requirement	7	100.% (144.)	71.42% (102.85)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N^N-LS_SVC: Investigated in Apr 2022 and no improvement can be made at this stage.

V_S_HEYWOOD_UFLS: Investigated in May 2022 and no improvement can be made at this stage.

V_MOORBWF_150_0SWT: Investigated in May 2022 and no improvement can be made at this stage.

Q-X_STR_7C8C_MEWF: Investigated in May 2022 and no improvement can be made at this stage.

Q_STR_7C2K_MEWF_3: Investigated in Apr 2022 and no improvement can be made at this stage.

Q-X_STR_7C8C_HAYSF: Investigated in Apr 2022 and no improvement can be made at this stage.

Q-X_STR_7C8C_DAYSF: Investigated in Apr 2022 and no improvement can be made at this stage.

Q-X_STR_7C8C_KEP: Investigated in Apr 2022 and no improvement can be made at this stage.

3 Generator / Transmission Changes

One of the main drivers for changes to constraint equations is from power system change, whether this is the addition or removal of plant (either generation or transmission). The following table details changes that occurred in April 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Liddell Unit 3	2 April 2022	NSW	Deregistered Generator
Mannum Adelaide Pumping Station No 3	12 April 2022	SA	New Generator
Happy Valley Battery (Load Component)	20 April 2022	SA	New Battery
Happy Valley Battery (Generation Component)	20 April 2022	SA	New Battery
Happy Valley Solar	20 April 2022	SA	New Generator

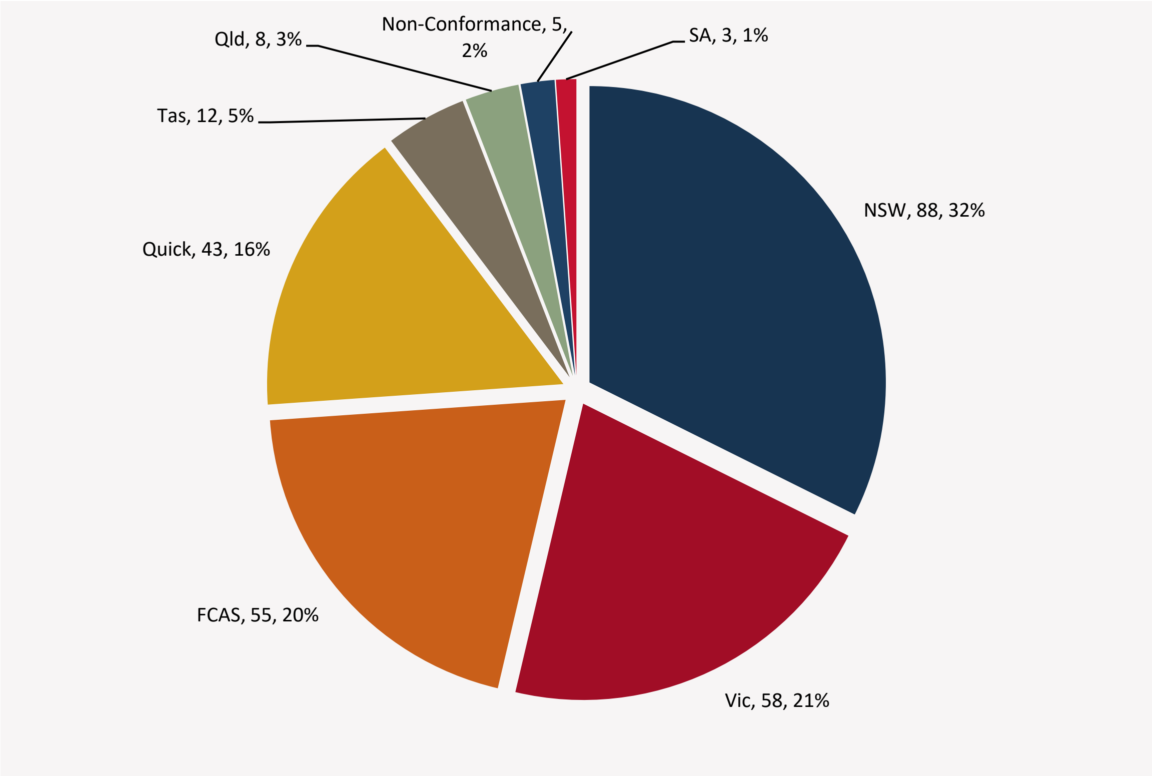
3.1 Constraint Equation Changes

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