Monthly Constraint Report

July 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 July 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	5830 (485.83)	Voltage Stability
Q^^NIL_QNI_SRAR	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	1565 (130.41)	Voltage Stability
Q_KEP-HYB_20MW	Kennedy Energy Park upper limit of 20MW	1508 (125.66)	Unit Zero
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	1215 (101.25)	Thermal
S^NIL_CRK+MTM_95	Out= Nil, upper limit for Cathedral Rocks WF + Mt Millar WF <= 95 MW to maintain voltage stability limits	988 (82.33)	Voltage Stability
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	959 (79.91)	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)	885 (73.75)	Discretionary
NSA_Q_GSTONE34_150	Gladstone 3+4 >= 150 for Network Support Agreement	769 (64.08)	Network Support
S_ISLE_LKB1+2+3_60	Discretionary upper limit on Lake Bonney (1+2+3) windfarms<=60 MW & No. in-service wind turbines for LKB at 41 Turbines.(Note otherwise, LKB 2+3 +1 will be constrained to 0 MW)	755 (62.91)	Discretionary
V>>V_NIL_18	Out= Nil, avoid O/L Ararat to Waubra 220kV line on trip of Kerang to Bendigo 220kV line, Feedback	729 (60.75)	Thermal

2.2 Top 10 binding impact constraint equations

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

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

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

Table 2 Top 10 binding impact network constraint equations

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Limit Type
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)	912,378	Discretionary
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	803,926	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	779,038	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	742,873	Thermal
V>>V_NIL_18	Out= Nil, avoid O/L Ararat to Waubra 220kV line on trip of Kerang to Bendigo 220kV line, Feedback	729,722	Thermal
Q_KEP-HYB_20MW	Kennedy Energy Park upper limit of 20MW	644,949	Unit Zero
N^^Q_LS_VC_B1	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	600,999	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	517,260	Thermal
V_BULGANAWF_FLT_0	Limit Bulgana Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	496,820	System Strength
S_ISLE_CANUNDA_35	Discretionary upper limit on Canunda windfarm<=35MW & No. in-service wind turbines for canunda at 23 Turbines.(Note otherwise,Canunda will be constrained to 0 MW)	433,554	Discretionary

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
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	50 (4.16)	Voltage Stability
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)	25 (2.08)	Unit Zero
NSA_Q_GSTONE34_150	Gladstone 3+4 >= 150 for Network Support Agreement	22 (1.83)	Network Support
N_FINLYSF1_0INV	Constraint to violate if Finley solar farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	19 (1.58)	System Strength
T_BLINK_TV_BID	Out = Nil, limit Basslink to 0 MW if Basslink bid zero. Constraint to swamp otherwise.	18 (1.5)	Other
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	7 (0.58)	System Strength
Q_STR_8C_7C2K_RGBSF	No limit to Rugby Run SF if Stan>=3+Cal>=2+Glad>=2+ (Stan+Cal+Glad) >=8,NQLD>450&470(AVG),Ross_FN>250&270(AVG), limit 50% if Stan>=2+Cal>=1+Glad>=3+ (Stan+Cal+Glad) >=7 + Kar>=2. Zero otherwise	6 (0.5)	System Strength
T^T_LIPM_1	Out = Liapootah to Waddamana to Palmerston 220 kV line, avoid voltage instability or violations for loss of the other Liapootah to Waddamana to Palmerston line	5 (0.41)	Voltage Stability
N^^Q_LS_VC_B1	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	2 (0.16)	Voltage Stability

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
N^N-LS_SVC	Constraint equation violated for 50 non-consecutive DI's between 04/07/2022 1835 hrs and 28/07/2022 1735 hrs with a max violation of 93 MW occurring on multiple DIs. Constraint violated due to competing requirements with import limits on the DirectLink interconnector which were set by #R025760_002_RAMP_F, #R025747_002_RAMP_F.
Q-MEWF_MVAR	Constraint equation violated for 25 consecutive DI's between 04/07/2022 between 1500 hrs and 1700 hrs with a violation degree of 0.001 MW. The constraint violated due to Mt Emerald Wind Farm exceeding their allowable MVAr limit.
NSA_Q_GSTONE34_150	Constraint equation violated for 22 non-consecutive DIs between 19/07/2022 0115 hrs and 27/07/2022 0310 hrs with a max violation of 20 MW occurring on 27/07/2022 at 0300 hrs. Constraint equation violated due to the combined availability of Gladstone units 3 and unit 4 being less than the Network Service Agreement requirement.
N_FINLYSF1_0INV	Constraint violated for 19 consecutive DIs between 25/07/2022 0730 hrs and 25/07/2022 0900 hrs with violation degree of 0.001 MW. Constraint equation violated due to Finley Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
T_BLINK_TV_BID	Constraint equation violated for 18 non-consecutive DI's between 01/07/2022 2205 hrs and 14/07/2022 2310 hrs with a max violation of 254.2 MW. Constraint violated due to Basslink being limited by its rate of change.
NRM_QLD1_NSW1	Constraint equation violated for 8 non-consecutive DI's on 04/07/2022 between 1740 hrs and 04/07/2022 1930 hrs with a max violation of 14.97 MW occurring at 1840 hrs. Constraint equation violated due to competing requirements with import limits on the DirectLink and QNI interconnector which were set by N^N-LS_SVC and N^^Q_LS_VC_B1.
V_KIAMSF_40INV	Constraint equation violated for 7 non-consecutive DI's on 06/07/2022 between 0755 hrs and 0825 hrs with a violation degree of 0.01 MW. Constraint violated due to Kiamal Solar Farm exceeding its inverter limit.
Q_STR_8C_7C2K_RGBSF	Constraint equation violated for 6 non-consecutive on 09/07/2022 between 0955 hrs and 1040 hrs with a violation degree of 0.01 MW. Constraint violated due to Rugby Run Solar Farm exceeding its MVAr limit
T^T_LIPM_1	Constraint equation violated for 5 non-consecutive DI's between 08/07/2022 0815 hrs and 0900 hrs with a max violation of 4.28 MW at 0820 hrs. Constraint violated due to post-contingent low fault level at Wadamanna, following the trip of a PA-WA-LI I220 kV line during the planned outage of other line.
N^^Q_LS_VC_B1	Constraint equation violated for 2 DI's on 05/07/2022 at 0825 hrs and 0830 hrs with a max violation of 164.3 MW at 0825 hrs. Constraint violated due to competing requirements with import limits on the DirectLink interconnector which were set by N_MBTE1_B and Q>NIL_MUTE

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	5646 (470.5)	-100.08 (-25.5)
Q^^NIL_QNI_SRAR	NSW1-QLD1 Import	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	1553 (129.42)	-987.56 (-1104.95)
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	1122 (93.5)	167.8 (191.16)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	870 (72.5)	46.5 (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	774 (64.5)	184.31 (965.41)
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	644 (53.67)	131.61 (-160.0)
V_VS_LB_CAN_50	V-SA Export	Limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement when SA is at risk of separation. Constraint swamp out when 2-4 syncons I/S	601 (50.08)	-17.9 (49.39)
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	514 (42.83)	-290.2 (-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	510 (42.5)	3.04 (439.01)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
V>>V_NIL_18	V-S-MNSP1 Import	Out= Nil, avoid O/L Ararat to Waubra 220kV line on trip of Kerang to Bendigo 220kV line, Feedback	495 (41.25)	141.87 (-152.01)

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

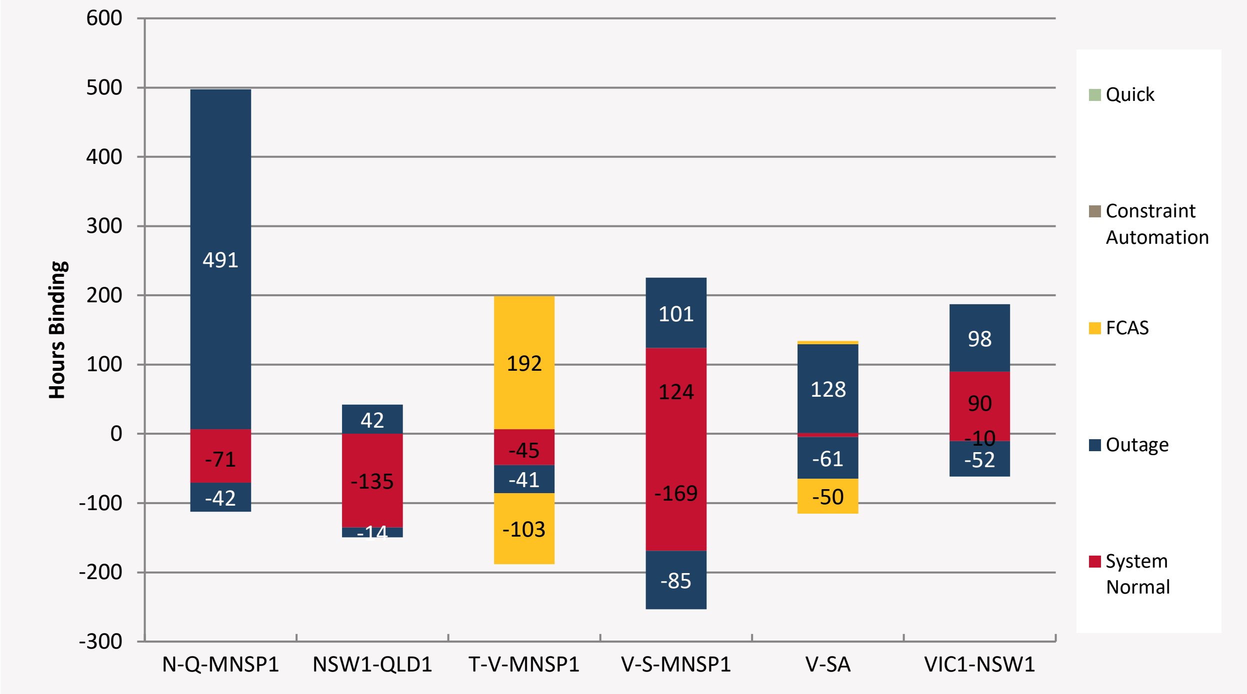
Non-real time constraint automation was not used.

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.

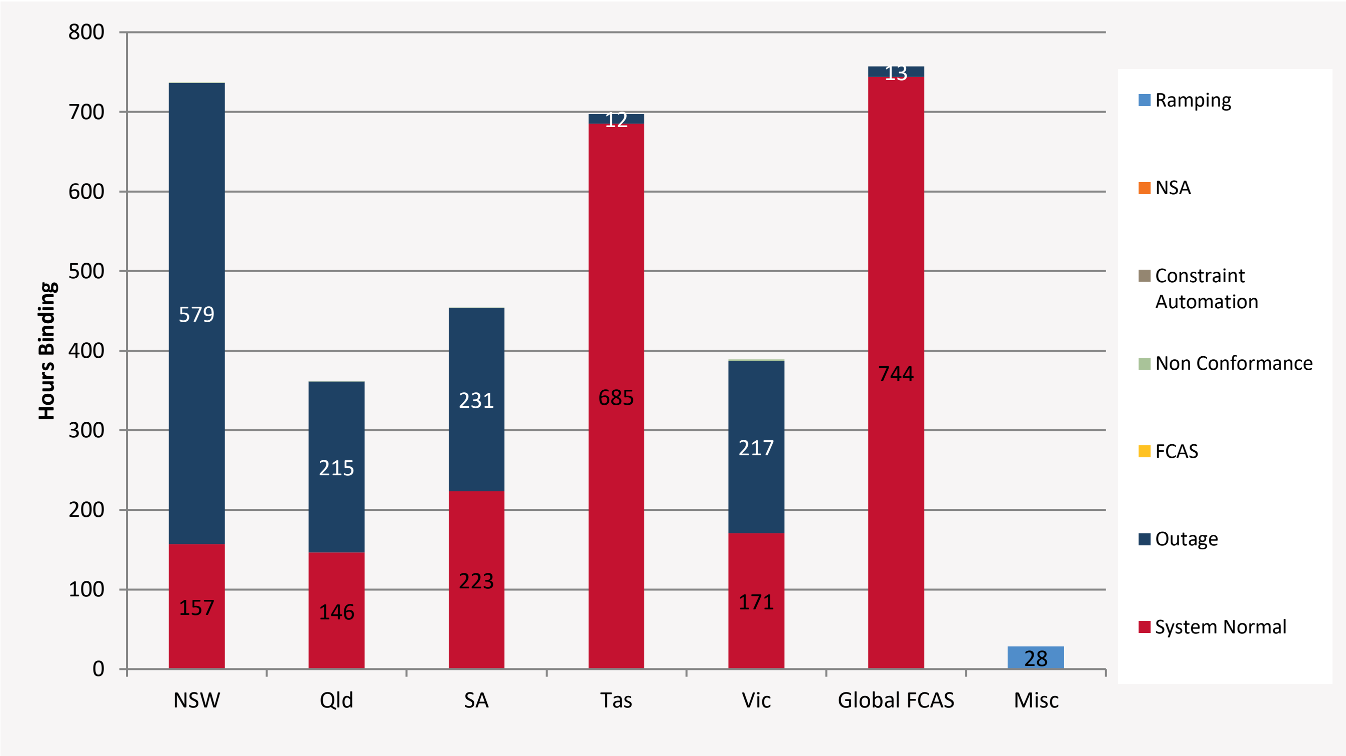
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

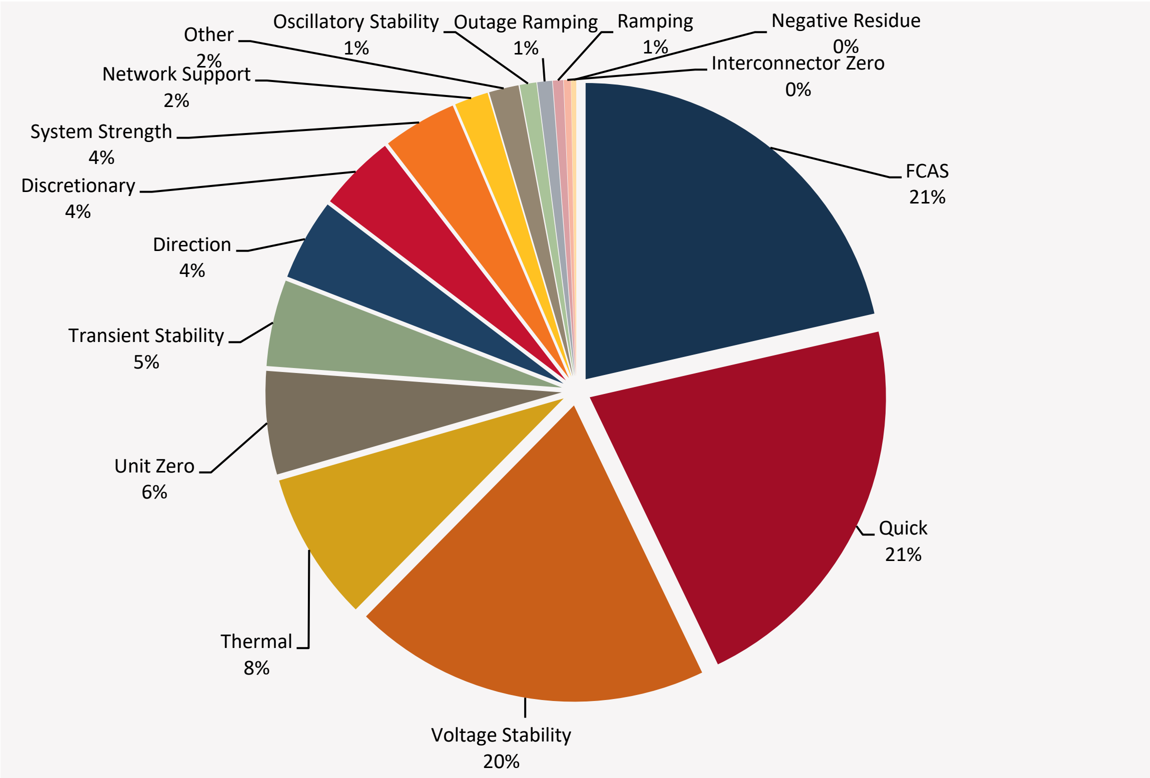
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

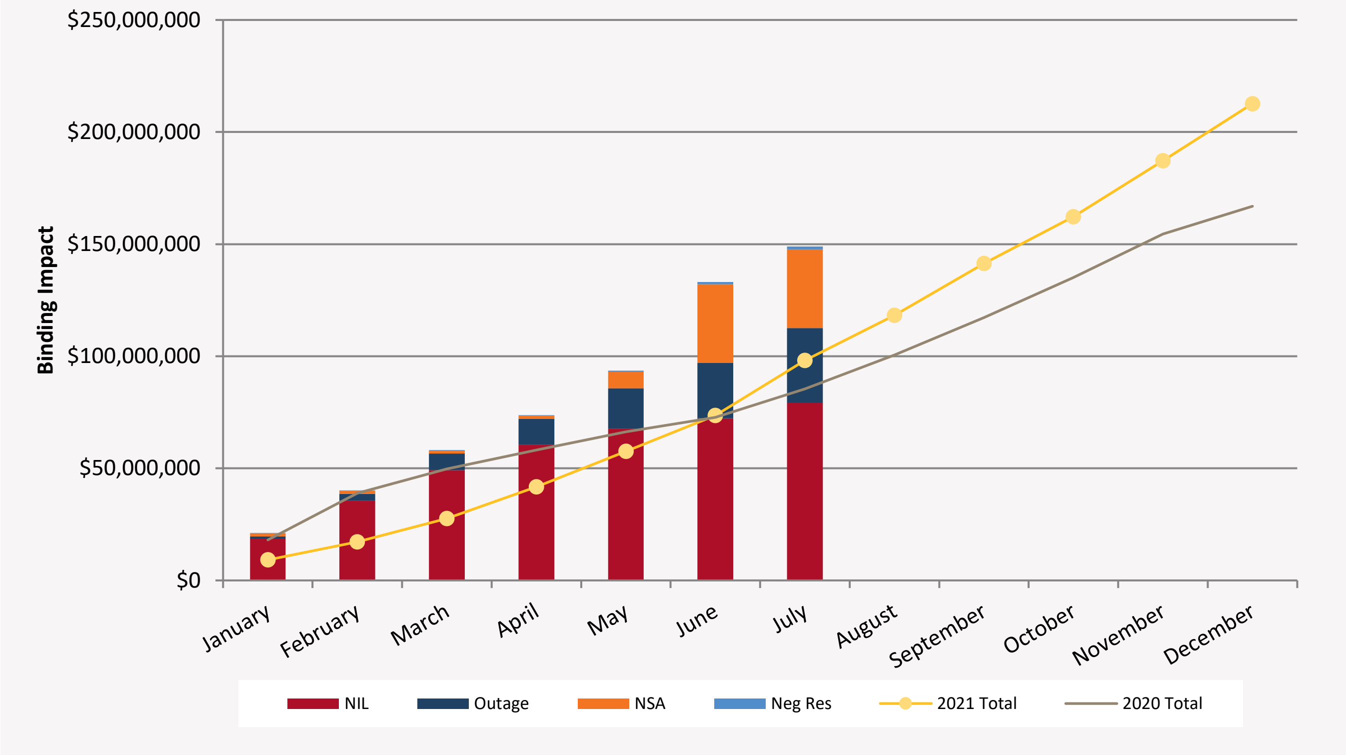
Figure 3 Binding by limit type



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
V::N_X_SMSC_V2	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 500kV.	65	245,525% (396.75)	4,478% (183.61)
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	1020	12,704% (107.47)	72.78% (24.96)
V::N_X_SMSC_O1	Out = both South Morang 330 kV series capacitor banks, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 220kV.	13	11,306% (175.87)	1,330% (124.38)
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.	42	10,971% (372.24)	488% (244.53)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V^SML_BUDP_3	Out = Buronga to Balranald (X3) or Balranald to Darlington Pt (X5) 220 kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	17	2,059% (159.42)	228% (51.28)
N^^V_DPWG_X5_RVYS_1	Out = Darlington Point to Wagga with line X5 open and Ravine to Yass (2+63) 330kV lines, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	3	579% (255.07)	290% (166.51)
N^^V_CNCW_1	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W), avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	114	549% (513)	66.52% (154.85)
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.	73	484% (27.06)	44.57% (9.03)
N^^V_SM_SCAP	Out = both South Morang 330 kV series capacitor banks, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	150	293% (513)	61.68% (155.59)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N^^V_DPWG_X5_RVYS_1: Investigated in July 2022 and no improvement can be made at this stage.

N^^V_SM_SCAP: Investigated in July 2022 and no improvement can be made at this stage.

V::N_X_SMSC_V2: Investigated and no improvement can be made to the constraint equation at this stage.

N^N-LS_SVC: Investigated and constraint equation was updated on 27/08 to improve PD performance.

V::N_X_SMSC_O1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_X_SMSC_O2: Investigated and no improvement can be made to the constraint equation at this stage.

V^SML_BUDP_3: 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.

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

V::N_SETB_S2: 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 July 2022.

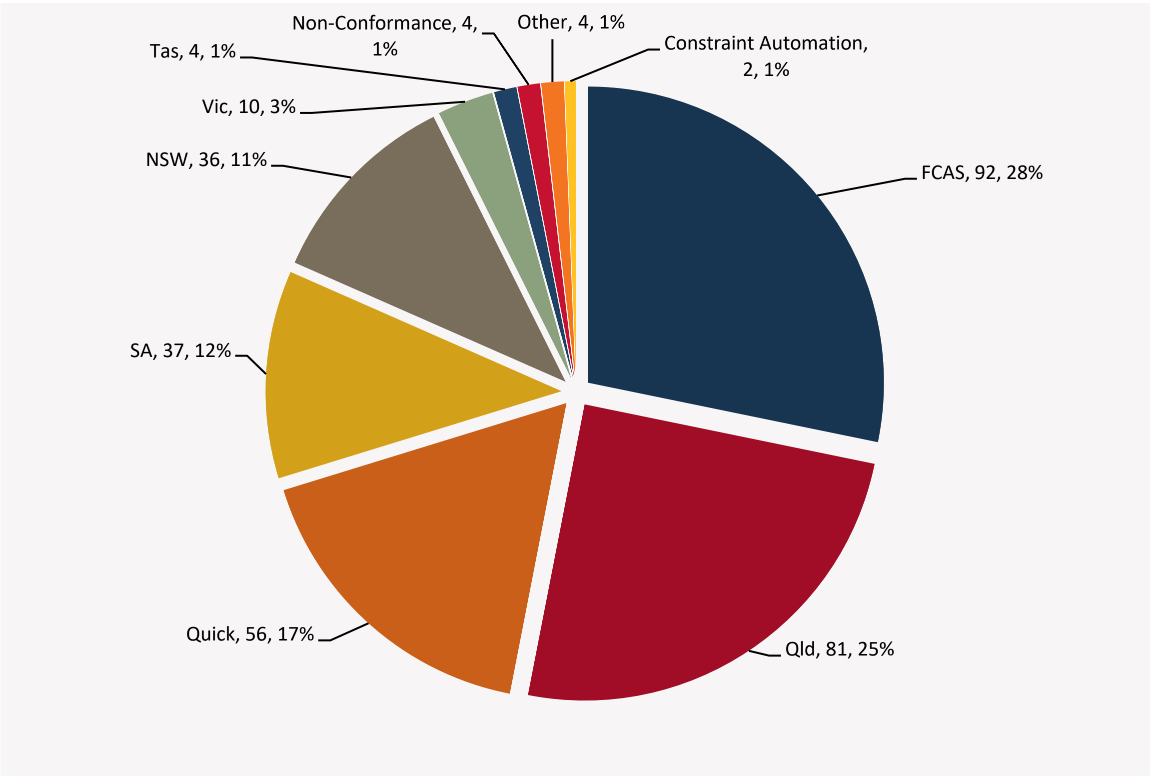
Table 7 Generator and transmission changes

Project	Date	Region	Notes
Queanbeyan BESS	5 July 2022	NSW	New Battery
Christie Beach Battery	12 July 2022	SA	New Battery

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



[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

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