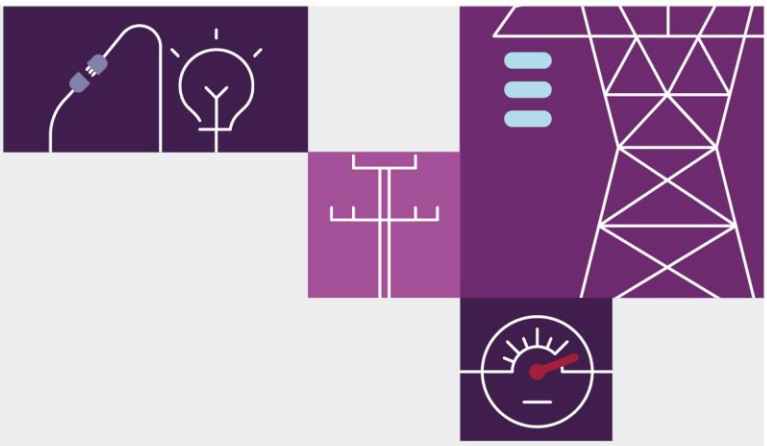
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

February 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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Contents

Tables

Figures

1 Introduction

This report details constraint equation performance and transmission congestion related issues for February 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; TG formulation only	5577 (464.75)	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	2643 (220.25)	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	2242 (186.83)	Voltage Stability
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	2142 (178.5)	Voltage Stability
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2045 (170.41)	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	1681 (140.08)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1650 (137.5)	Thermal
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	1417 (118.08)	Thermal
N>N-NIL_PK_TX1	Out= Nil, avoid O/L Parkes TX1 132/66kV transformer on trip of Nil, Feedback	928 (77.33)	Thermal
N^^Q_NIL_A	Out= Nil, avoid Voltage Collapse on loss of Liddell to Muswellbrook (83) line	898 (74.83)	Voltage Stability

2.2 Top 10 binding impact constraint equations

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

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

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

Table 2 Top 10 binding impact network constraint equations

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Limit Type
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	3,006,655	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	2,107,797	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	1,953,046	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1,708,899	Thermal
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	1,480,296	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	1,346,906	Voltage Stability
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	1,205,328	Voltage Stability
V>>V_NIL_18	Out= Nil, avoid O/L Ararat to Waubra 220kV line on trip of Kerang to Bendigo 220kV line, Feedback	507,309	Thermal
N>N-MOON_945_94K	Out= Molong to Orange North (94T) 132kV line, avoid O/L Molong to Wellington (945/1) on trip of Parkes to Wellington (94K) line, Feedback	477,589	Thermal
N^^Q_NIL_A	Out= Nil, avoid Voltage Collapse on loss of Liddell to Muswellbrook (83) line	451,605	Voltage Stability

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.

[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.

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; TG formulation only	19 (1.58)	Voltage Stability
N>N-GITN_TE_C1	Out= Glen Innes to Tenterfield (96R), avoid O/L Koolkhan to Lismore (967) on trip of Coffs Harbour to Lismore (89), Swamp out when all 3 directlink cable O/S, Feedback, TG formulation in PD/ST	13 (1.08)	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	10 (0.83)	Thermal
F_T+NIL_MG_R60	Out = Nil, Raise 60 sec requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	9 (0.75)	FCAS
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.	9 (0.75)	Thermal
NC_S_MWPS3PV1	Non Conformance Constraint for MORGAN-WHYALLAPS3	4 (0.33)	Non-Conformance
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	3 (0.25)	FCAS
F_T++CSGO_TG_R5	Out = one Chapel St to Gordon line, Tasmania Raise 5 min requirement for loss of the remaining Chapel St to Gordon line, Basslink able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	2 (0.16)	FCAS
F_T+CSGO_TG_R6_2	Out = one Chapel St to Gordon line, Tasmania Raise 6 sec requirement for loss of the remaining Chapel St to Gordon line, Basslink unable to transfer FCAS, Segment2	2 (0.16)	FCAS
F_T+NIL_MG_RECL_R60	Out = Nil, Raise 60 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	1 (0.08)	FCAS

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 violated for 19 non-consecutive DIs with a max violation of 97.71 MW occurring on 02/02/2022 at 1720 hrs. For 4 DIs on 08/02/2022 the constraint violated due to a DirectLink control issue. For the remaining 15 DIs the constraint violated due to competing requirements with import limits on the DirectLink interconnector which were set by QNTE_ROC, Q>NIL_MUTE_757, N_X_MBTE_3B, and #R024746_002_RAMP_F.
N>N-GITN_TE_C1	Constraint violated for 13 non-consecutive DIs on 02/02/2022 between 0700 hrs and 0925 hrs with a max violation of 10.7 MW occurring on 02/02/2022 at 0925 hrs. Constraint violated due to DirectLink dispatch target oscillating during a planned outage of Glen Innes – Tenterfield 132 kV line.
N>>N-NIL_969	Constraint violated for 10 non-consecutive DIs on 28/02/2022 between 0815 hrs and 1010 hrs with a max violation of 13.99 MW occurring on 28/02/2022 at 1005 hrs. Constraint violated due to commissioning test by Gunnedah Solar Farm.
F_T+NIL_MG_R60	Constraint violated for 9 non-consecutive DIs with a max violation of 47.34 MW occurring on 01/02/2022 at 0150 hrs. Constraint violated due to the Tasmania raise 60 second availability being lower than the requirement.
Q>N-MUTE_758	Constraint violated for 9 non-consecutive DIs with a max violation of 31.87 MW occurring on 18/02/2022 at 1530 hrs. Constraint violated due to competing requirements with export limits on the DirectLink interconnector which were set by N^N-LS_SVC.

Constraint Equation ID (System Normal Bold)	Description
NC_S_MWPS3PV1	Constraint violated for 4 consecutive DIs on 18/02/2022 from 1620 hrs to 1635 hrs with a violation degree of 0.2 MW. Constraint violated due to non-compliance by Morgan Whyalla 3 Solar Farm.
F_T_AUFLS2_R6	Constraint violated for 3 DIs on 24/02/2022 at 0705 hrs and 0710 hrs and on 28/02/2022 at 1040 hrs with a max violation of 33.53 MW occurring on 24/02/2022 at 0705 hrs. Constraint violated due to the Tasmania raise 6 second availability being lower than the requirement.
F_T++CSGO_TG_R5	Constraint violated for 2 DIs, on 17/02/2022 at 0805 hrs and 0810 hrs with a max violation of 38.43 MW occurring on 17/02/2022 at 0810 hrs. Constraint violated due to the Tasmania raise 5 minute availability being lower than the requirement.
F_T+CSGO_TG_R6_2	Constraint violated for 2 DIs on 24/02/2022 at 0705 hrs and 0710 hrs with a max violation of 13.69 MW occurring on 24/02/2022 at 0705 hrs. Constraint violated due to the Tasmania raise 6 second availability being lower than the requirement.
F_T+NIL_MG_RECL_R60	Constraint violated for 1 DI on 15/02/2022 at 0015 hrs with a violation degree of 52.83 MW. Constraint violated due to the Tasmania raise 60 second availability being lower than the requirement.

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; TG formulation only	4865 (405.42)	-64.97 (31.85)
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	2603 (216.92)	159.48 (190.74)
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	2045 (170.42)	36.88 (957.36)
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	1190 (99.17)	153.19 (-42.45)
V^^V_NIL_KGTS	V-S-MNSP1 Import	Out= Nil, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	1172 (97.67)	147.4 (-120.43)
F_MAIN++ML_L6_0400	T-V-MNSP1 Import	Out = Nil, Lower 6 sec requirement for a Mainland Load Event, ML = 400, Basslink able transfer FCAS	1126 (93.83)	-399.99 (-439.0)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1104 (92.0)	-127.56 (404.6)
N^^Q_NIL_A	NSW1-QLD1 Export	Out= Nil, avoid Voltage Collapse on loss of Liddell to Muswellbrook (83) line	896 (74.67)	490.84 (705.5)
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	782 (65.17)	-427.14 (-439.01)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	693 (57.75)	-167.69 (400.64)

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_BRIS_511836F4	11/02/2022 10:40 to 11/02/2022 18:40	Constraint was invoked due to trip of Molong to Orange North (94T) 132 kV line to avoid overloading the Wellington to Orange North (947) 132kV line on trip of Wellington to Mt Piper (72) 330kV line.
CA_BRIS_5120191F	17/02/2022 09:55 to 17/02/2022 10:05	Constraint was invoked to avoid overloading the Buronga to Redcliff (OX1) 220 kV line on trip of Wodonga to Jindera (060) 330 kV line.
CA_BRIS_51201D29	17/02/2022 10:10 to 17/02/2022 12:00	Same reason as above.
CA_SYDS_5125A47F	21/02/2022 14:45 to 21/02/2022 15:30	Constraint was invoked to avoid overloading Balranald to Buronga (X3) 220 kV line on trip of Wodonga to Jindera (060) 330 kV line during the outage of Lower Tumut to Yass (03) 330 kV line.

2.5.1 Further Investigation

CA_BRIS_511836F4: Two new constraint sets, N-MOON_94T and N-X_MOON_WLTX, have been created to manage the outage of the Molong to Orange North (94T) 132 kV line in the future.

CA_BRIS_5120191F: A new constraint, N>>V-NIL_0X1_60, has been created to manage this scenario in the future.

CA_BRIS_51201D29: Same as above.

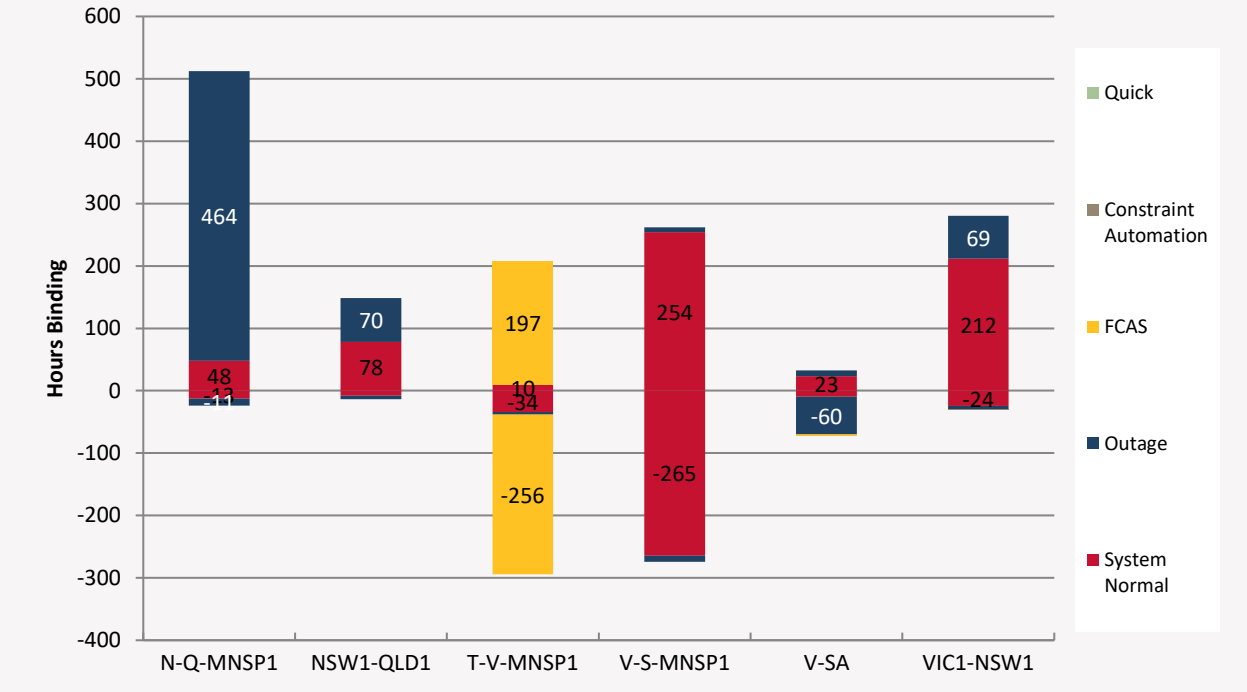
CA_SYDS_5125A47F: A new constraint, N>>N-NIL_X3_060, has been created to manage this scenario in the future.

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.

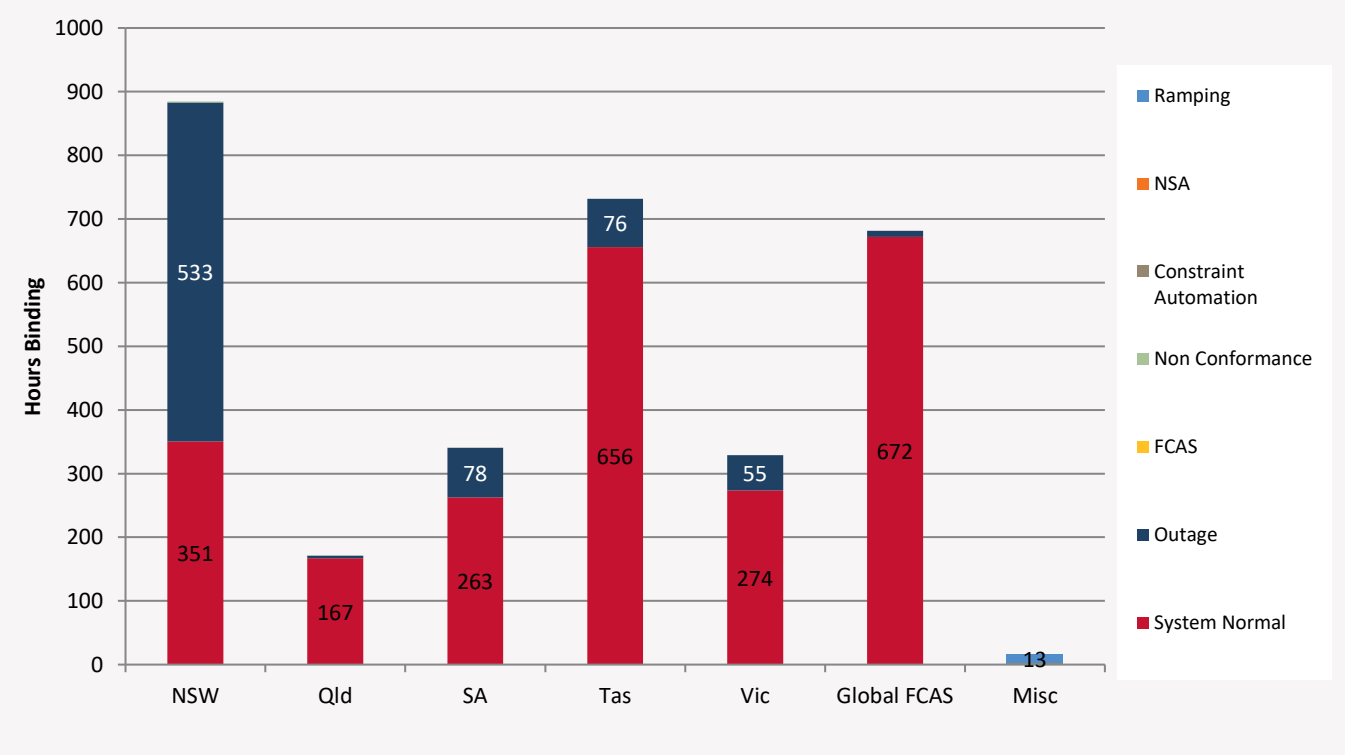
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

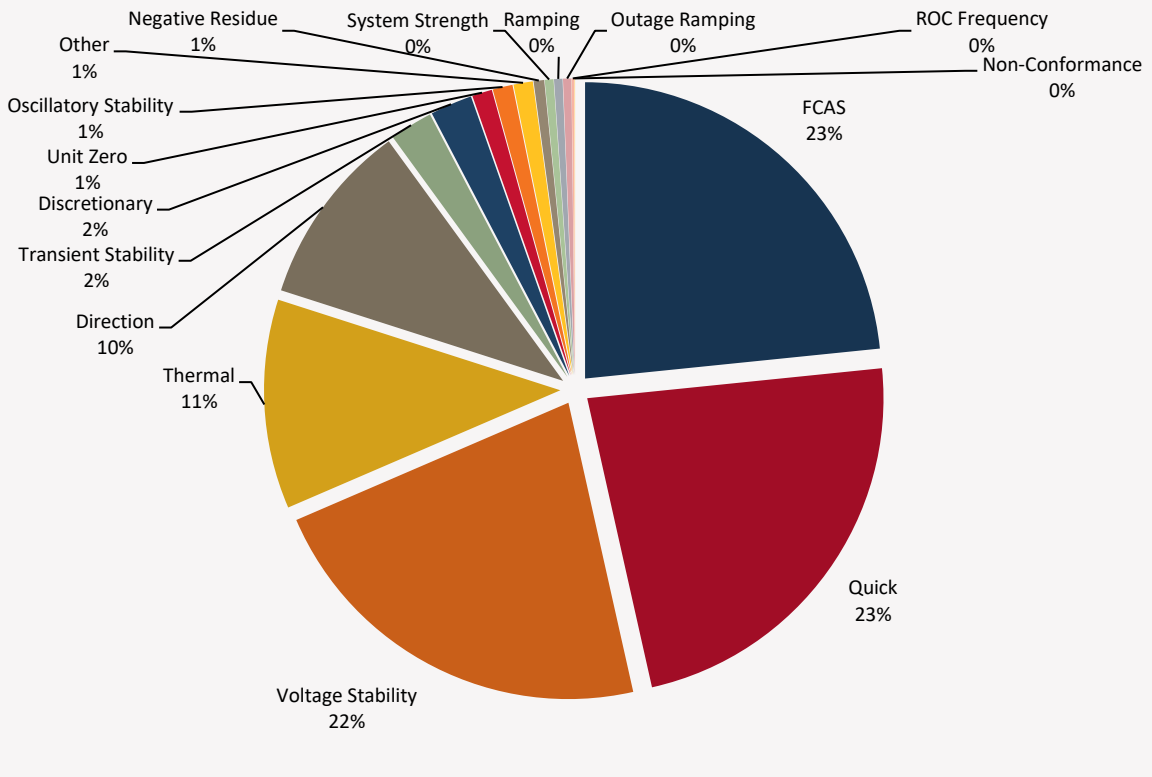
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

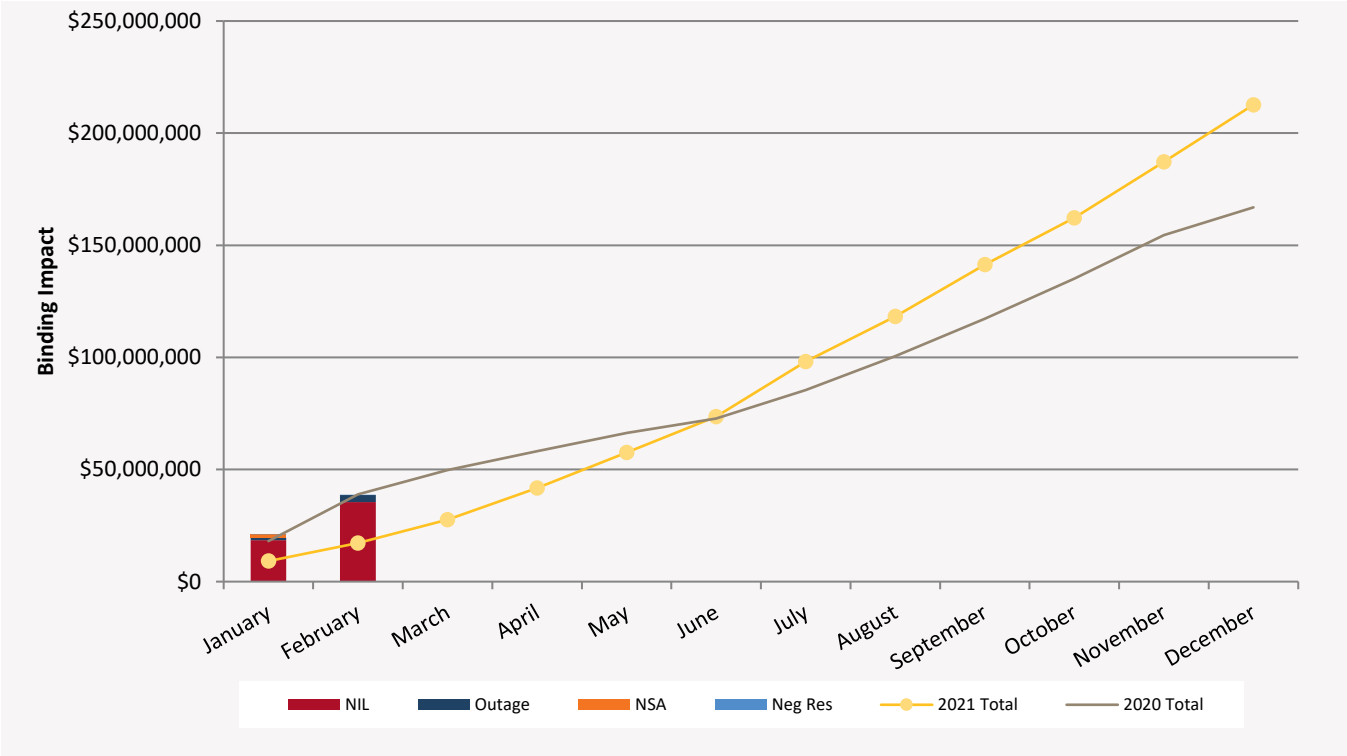
Figure 3 Binding by limit type



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; TG formulation only	992	9,643% (126.17)	116.48% (25.58)
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	6	746% (49.53)	197% (32.75)
N>>N-NIL__2_OPENED	Out= Nil, avoid O/L Liddell to Tamworth (84) using 15 mins rating on trip of Liddell to Muswellbrook (83) line, Feedback	10	448% (443.11)	262% (300.38)
S^NIL_MTM_VCS_STATUS	Out= Nil, upper limit for Mt Millar WF based on Mt Millar Voltage Control System (VCS) availability, (Note: MTM <=16 MW when VCS OFF; MTM<= 70 MW when VCS ON)	5	338% (54.)	338% (54.)
N>N-NIL_LSDU	Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6), Feedback	13	187% (81.71)	107.02% (46.72)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	366	169% (241.73)	17.75% (27.9)
V^^SML_NSWRB_2	Out = NSW Murraylink runback scheme, VIC to SA transfer limit on Murraylink to avoid voltage collapse at Red Cliffs for the loss of either the Darlington Point to Balranald (X5) or Balranald to Buronga (X3) 220kV lines	26	115.84% (247.93)	57.46% (126.55)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	34	110.42% (26.5)	34.75% (9.21)
Q>NIL_MUTE_757	Out= Nil, ECS for managing 757 H4 Mudgeeraba to T174 Terranora 110kV line, Summer and Winter ECS ratings selected by SCADA status.	10	98.33% (99.95)	93.45% (99.95)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated or are being investigated:

N^N-LS_SVC: 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>>N-NIL__2_OPENED: Investigated and no improvement can be made to the constraint equation at this stage.

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

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

N>>N-NIL_94T: Investigated and no improvement can be made to the constraint equation at this stage.

V^^SML_NSWRB_2: Investigated and no improvement can be made to the constraint equation at this stage.

N_X_MBTE_3A: Investigated and no improvement can be made to the constraint equation at this stage.

Q>NIL_MUTE_757: 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 February 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Bluegrass Solar Farm	1 February 2022	Qld	New Generator
Murra Warra 2 Wind Farm	15 February 2022	Victoria	New Generator
Demand Response – Enel X Vic 17	22 February 2022	Victoria	New registration for Wholesale Demand Response

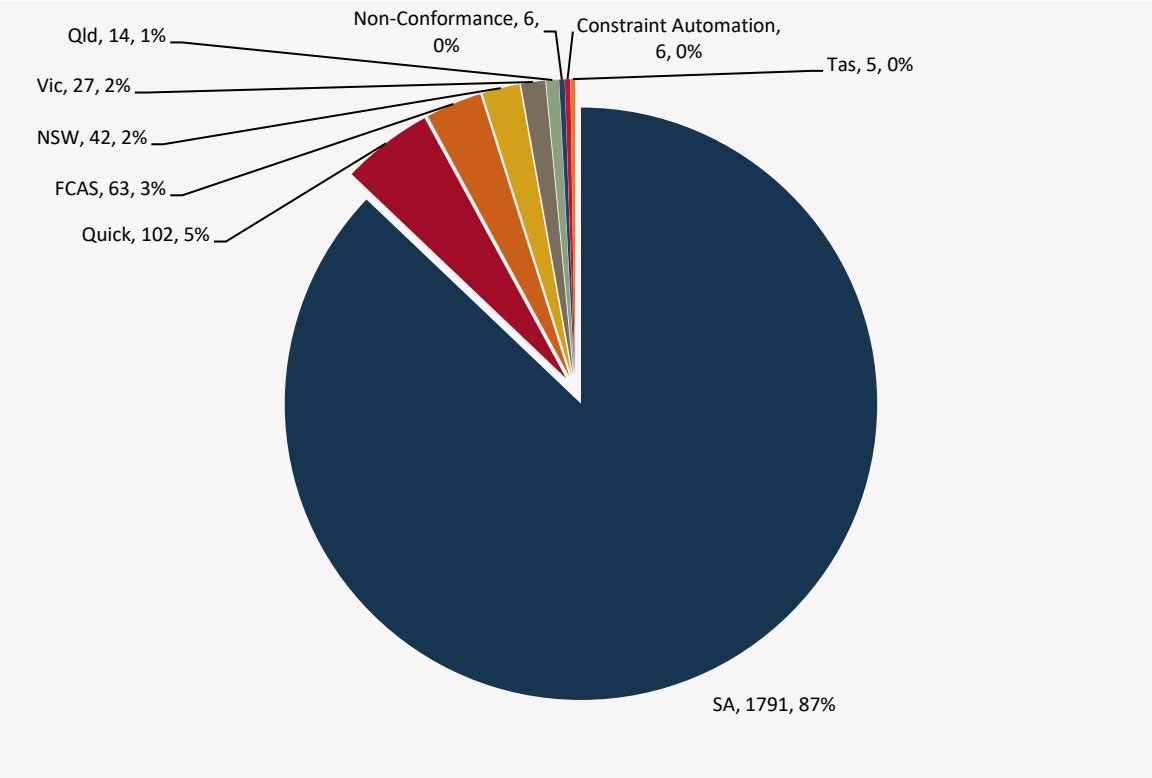
3.1 Constraint Equation Changes

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