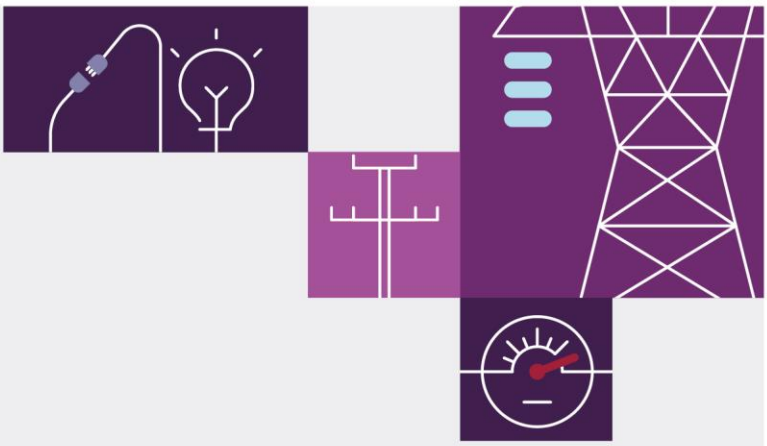
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

January 2023

A report for the National Electricity Market on Constraint results.



Important notice

Purpose

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

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Contents

Tables

Figures

1 Introduction

This report details constraint equation performance and transmission congestion related issues for January 2023. Included are investigations of violating constraint equations, usage of the constraint automation and performance of Pre-dispatch constraint equations. Transmission and generation changes are also detailed along with the number of constraint equation changes.

2 Constraint Equation Performance

2.1 Top 10 binding constraint equations

A constraint equation is binding when the power system flows managed by it have reached the applicable thermal or stability limit or the constraint equation is setting a Frequency Control Ancillary Service (FCAS) requirement. Normally there is one constraint equation setting the FCAS requirement for each of the eight services at any time. This leads to many more hours of binding for FCAS constraint equations - as such these have been excluded from the following table.

Table 1 Top 10 binding network constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	3213 (267.75)	Thermal
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; [Swamped for three DLK cables are O/S or Swamped when ECS is enabled with DLK is exporting to QLD, sets DLK to -29 MW for -29< DLK FLOW<0)	2865 (238.75)	Voltage Stability
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	2692 (224.33)	Thermal
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	2440 (203.33)	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	2288 (190.66)	Voltage Stability
Q_KEP-HYB_25MW	Kennedy Energy Park upper limit of 25MW	2118 (176.5)	Discretionary
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line. Murraylink VFRB disabled. Swamp if Murraylink VFRB enabled.	1992 (166.0)	Voltage Stability
NSA_S_POR01_ISLD	Network Support Agreement for Port Lincoln Units 1 and 2 to meet local islanded demand for the planned outage.	1904 (158.66)	Network Support
NSA_S_POR03_ISLD	Network Support Agreement for Port Lincoln Unit 3 to meet local islanded demand for the planned outage.	1904 (158.66)	Network Support
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1629 (135.75)	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
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	3,358,507	Thermal
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1,909,301	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1,841,468	Thermal
N>>NIL_970_051	Out= NIL, avoid O/L BurJK to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	1,270,040	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	1,265,163	Voltage Stability
N>NIL_9R6_9R5	Out= Nil, avoid O/L Wagga North to Wagga132 (9R6) on trip of Wagga North to Wagga330 (9R5) line, Feedback	1,056,671	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	860,675	Thermal
S>NIL_NWRB2_NWRB1	Out= NIL, avoid O/L North West Bend-Roberstown #1 132kV line on trip of North West Bend-Robertstown #2 132kV line (this trips MWP1-3 SFs), Feedback	832,048	Thermal
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line. Murraylink VFRB disabled. Swamp if Murraylink VFRB enabled.	813,798	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	724,068	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
V_KIAMSF_40INV_DYN	Limit Kiamal Solar Farm upper limit to 0 MW if number of inverter available exceeds 40 and Murra Warra 2 WF Syncon O/S. Constraint swamps out otherwise. DS only	20 (1.66)	System Strength
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	11 (0.91)	FCAS
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	5 (0.41)	FCAS
NSA_S_POR01_ISLD	Network Support Agreement for Port Lincoln Units 1 and 2 to meet local islanded demand for the planned outage.	2 (0.16)	Network Support
F_T+NIL_ML_L6	Out = Nil, Lower 6 sec requirement for a Tasmania Load Event, Basslink unable to transfer FCAS	1 (0.08)	FCAS
F_T+NIL_WF_TG_R6	Out= Nil, Tasmania Raise 6 sec requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby, Waddamana to Cattle Hill or Pieman to Granville Harbour line, Basslink unable to transfer FCAS	1 (0.08)	FCAS
N_FINLYSF1_0INV	Constraint to violate if Finley solar farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	1 (0.08)	System Strength
N_METZSF_25INV	Constraint to violate if Metz Solar Farm inverter availability greater than 25. Constraint swamp out otherwise. DS only	1 (0.08)	System Strength

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
V_KIAMSF_40INV_DYN	The constraint equation violated for 20 non-consecutive DIs on 03/01/2023 from 1055 hrs to 1140 hrs and 30/01/2023 from 0635 hrs to 0720 hrs with a max violation degree of 0 MW. Constraint equation violated due to Kiamal Solar Farm exceeding its inverter limit when Murra Warra synchronous condenser was out of service.
F_T_AUFLS2_R6	The constraint equation violated for 11 non-consecutive DIs between14/01/2023 1225 hrs and 27/01/2023 2230 hrs with a max violation of 27.55 MW occurring at 18/01/2023 1130 hrs. The constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
F_T+NIL_MG_RECL_R6	The constraint equation violated for 5 non-consecutive DIs between 17/01/2023 0810 hrs and 27/01/2023 2225 hrs with a max violation of 27.22 MW occurring at 17/01/2023 0815 hrs. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
NSA_S_POR01_ISLD	The constraint equation violated for 2 DIs on 18/01/2023 at 0500 hrs and 0505 hrs with a max violation of 15.13 MW occurring at 0505 hrs. Constraint violated due to the start-up profile of Port Lincoln Units 1 and 2.
F_T+NIL_ML_L6	The constraint equation violated for 1 DI on 12/01/2023 0835 hrs with a max violation degree of 63.18 MW. Constraint equation violation occurred due to the Tasmania lower 6 second availability being lower than the requirement.
F_T+NIL_WF_TG_R6	The constraint equation violated for 1 DI on 25/01/2023 1105 hrs with a violation degree of 0.62 MW. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
N_FINLYSF1_0INV	The constraint equation violated for 1 DI on 30/01/2023 at 1835 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
N_METZSF_25INV	The constraint equation violated for 1 DI on 30/01/2023 at 0945 hrs with violation degree of 0.001 MW. Constraint equation violated due to Metz Solar Farm exceeding its inverter limit.

2.4 Top 10 binding interconnector limit setters

Binding constraint equations can set the interconnector limits for each of the interconnectors on the constraint equation left-hand side (LHS). Table 5 lists the top (by binding hours) interconnector limit setters for all the interconnectors in the NEM and for each direction on that interconnector.

Table 5 Top 10 binding interconnector limit setters

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N^N-LS_SVC	N-Q-MNSP1 Export	Out= Lismore SVC O/S or reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; [Swamped for three DLK cables are O/S or Swamped when ECS is enabled with DLK is exporting to QLD, sets DLK to -29 MW for -29< DLK FLOW<0)	2806 (233.83)	-52.75 (95.99)
F_MAIN++APD_TL_L6	T-V-MNSP1 Import	Out = Nil, Lower 6 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	1756 (146.33)	-411.77 (-447.0)
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	1669 (139.08)	96.52 (1118.15)
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	1583 (131.92)	-407.84 (-447.0)
S>NIL_NWRB2_NWRB1	V-S-MNSP1 Export	Out= NIL, avoid O/L North West Bend-Roberstown #1 132kV line on trip of North West Bend-Robertstown #2 132kV line (this trips MWP1-3 SFs), Feedback	1526 (127.17)	168.62 (217.01)
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	1381 (115.08)	159.47 (-135.62)
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	1326 (110.5)	-418.65 (-448.0)
S>NIL_MHNW1_MHNW2	V-S-MNSP1 Export	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	1225 (102.08)	176.95 (215.87)
V^^V_NIL_KGTS	V-S-MNSP1 Import	Out= Nil, avoid voltage collapse for loss of Horsham - Murra Warra - Kiamal 220kV line. Murraylink VFRB disabled. Swamp if Murraylink VFRB enabled.	1160 (96.67)	153.99 (-157.71)
N>>NIL_970_051	VIC1-NSW1 Export	Out= NIL, avoid O/L BurJK to Yass (970) on trip of Wagga to Lower Tumut (051) line, Feedback	626 (52.17)	-119.23 (1018.33)

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_52C88A79	05/01/2023 08:35 to 05/01/2023 17:00	Constraint was invoked to avoid overload of Murray-Lower Tumut 65 330kV line for trip of Lower Tumut- Wagga 051 330 kV line.
CA_SYDS_52C76ACC	04/01/2023 12:10 to 04/01/2023 16:30	Constraint was invoked to avoid overload of Murray-Lower Tumut 65 330kV line for trip of Lower Tumut- Wagga 051 330 kV line.

2.5.1 Further Investigation

CA_SYDS_52C88A79: Constraint was invoked and binding. Constraint was revoked after a new constraint, N>>NIL_YSTX_051 was built to manage ongoing and future violation issues.

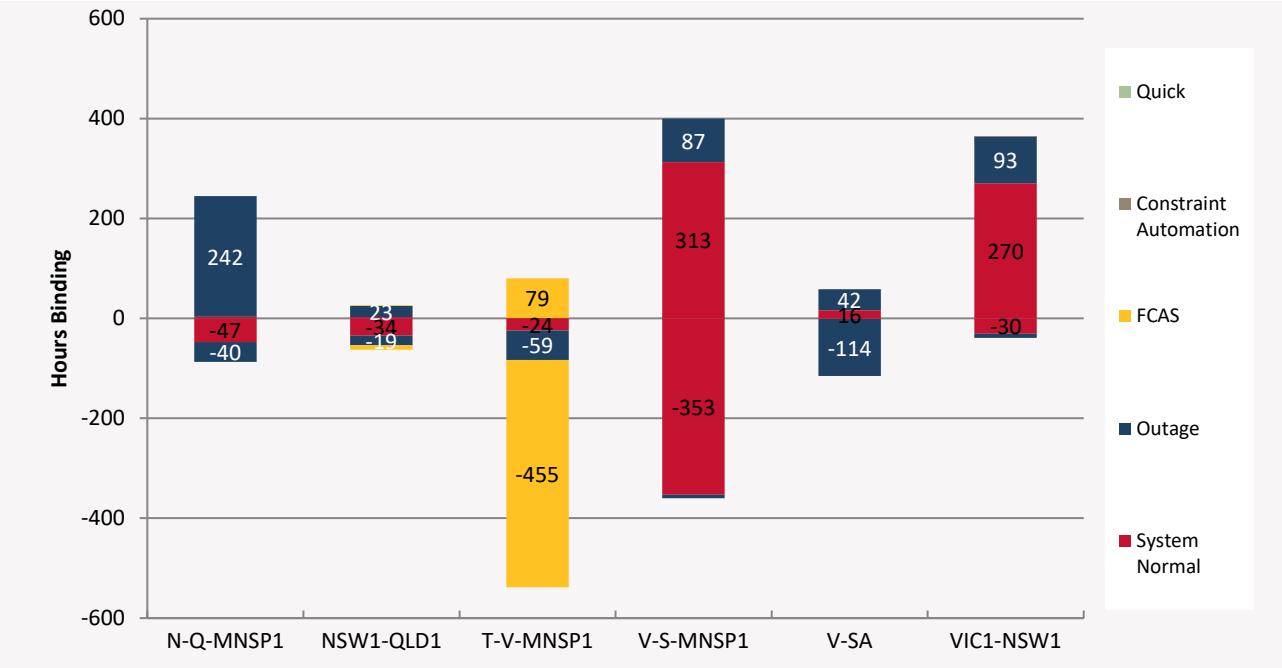
CA_SYDS_52C76ACC: Constraint was invoked and binding. Constraint was revoked after a new constraint, V>>N_NIL_65_051 was built to manage ongoing and future violation issues.

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.

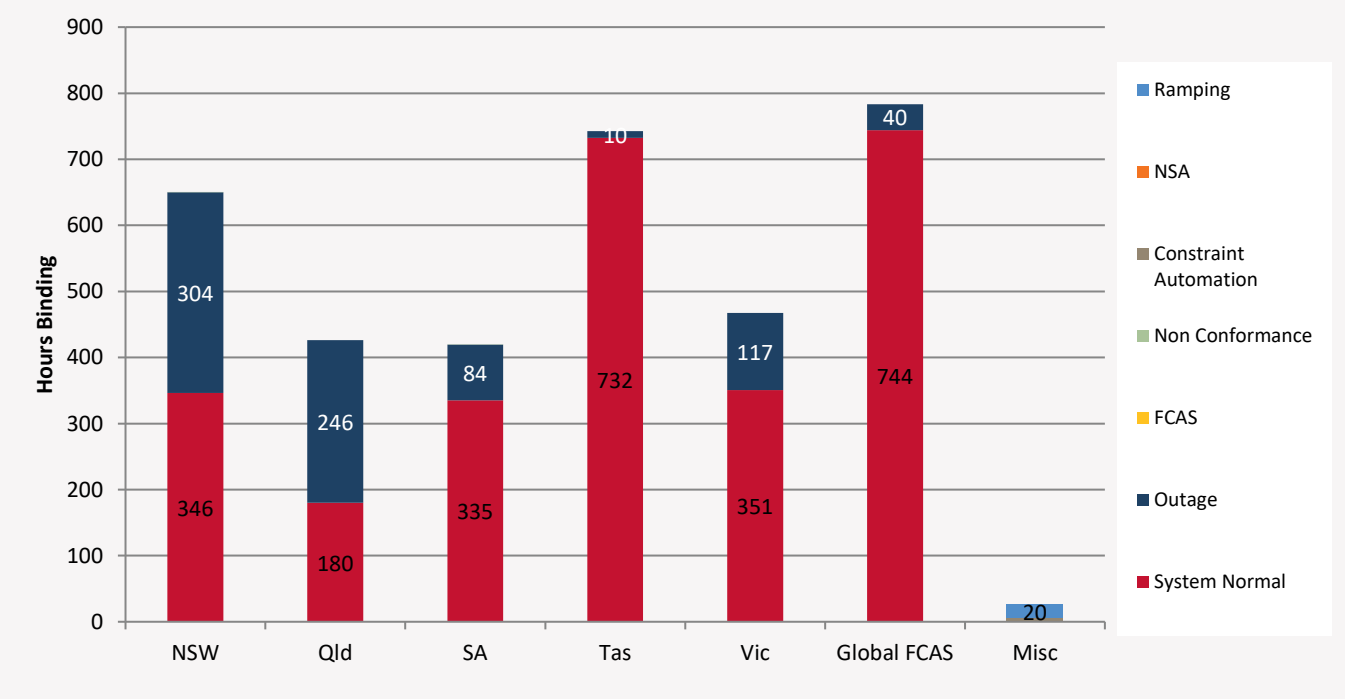
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

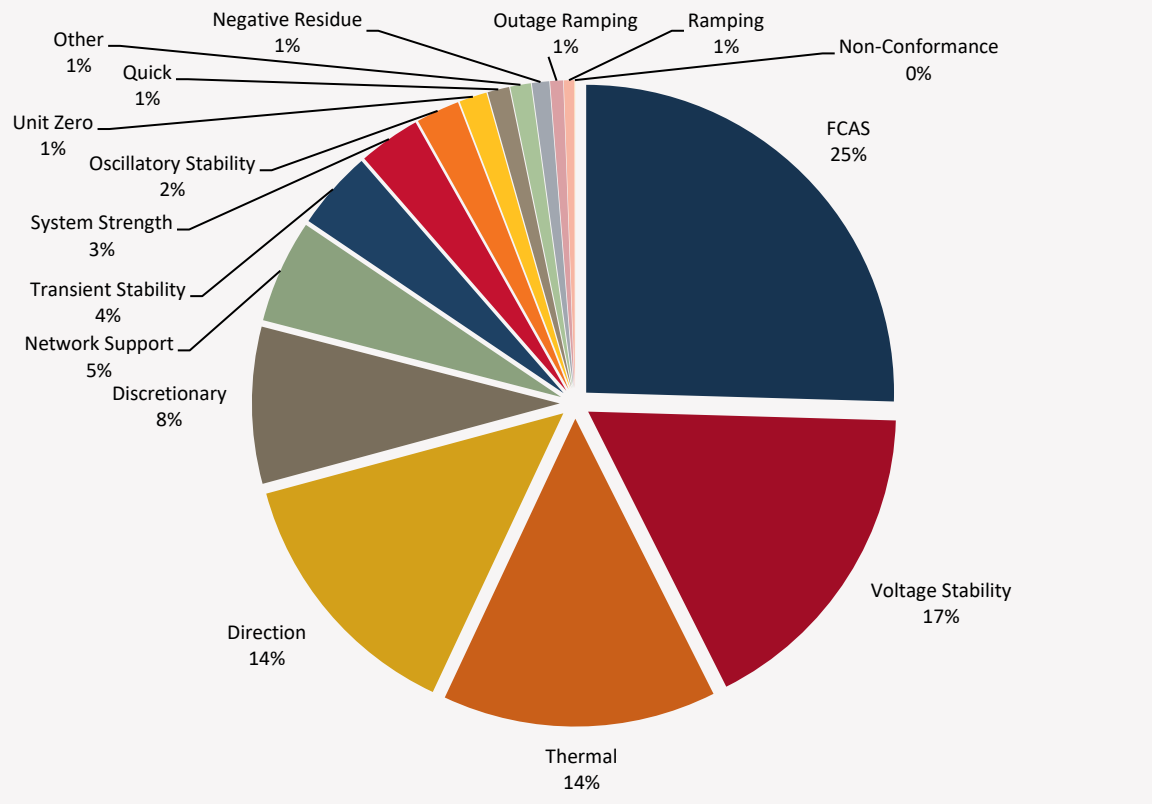
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

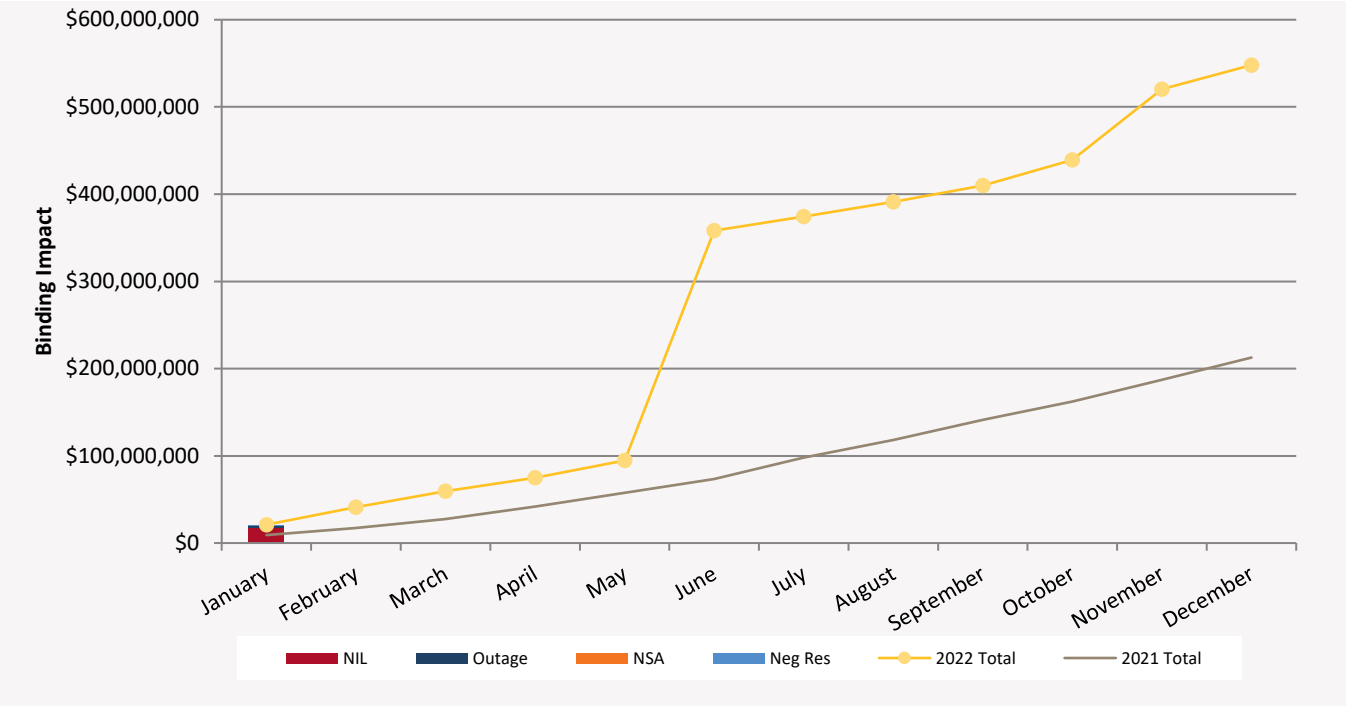
Figure 3 Binding by limit type



2.8 Binding Impact Comparison

The following graph compares the cumulative binding impact (calculated by summating the marginal values from the MCC re-run – the same as in section 2.2) for each month for the current year (indicated by type as a stacked bar chart) against the cumulative values from the previous two years (the line graphs). The current year is further categorised into system normal (NIL), outage, network support agreement (NSA) and negative residue constraint equation types.

Figure 4 Binding Impact comparison



2.9 Pre-dispatch RHS Accuracy

Pre-dispatch RHS accuracy is measured by the comparing the dispatch RHS value and the pre-dispatch RHS value forecast four hours in the future. The following table shows the pre-dispatch accuracy of the top ten largest differences for binding (in dispatch or pre-dispatch) constraint equations. This excludes FCAS constraint equations, constraint equations that violated in Dispatch, differences larger than ±9500 (this is to exclude constraint equations with swamping logic) and constraint equations that only bound for one or two Dispatch intervals. AEMO investigates constraint equations that have a Dispatch/Pre-dispatch RHS difference greater than 5% and ten absolute difference which have either bound for greater than 25 dispatch intervals or have a greater than $1,000 binding impact. The investigations are detailed in 2.9.1.

Table 6 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; [Swamped for three DLK cables are O/S or Swamped when ECS is enabled with DLK is exporting to QLD, sets DLK to -29 MW for -29< DLK FLOW<0)	630	62,264% (101.67)	371% (30.06)
V>>V_DDSM_1	Out= Dederang to South Morang 330kV line, avoid O/L Ballarat to Bendigo 220kV line on trip of the remaining South Morang to Dederang 330kV line, Feedback	27	3,967% (282.64)	323% (113.1)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	12	317% (30.1)	104.41% (10.82)
T::T_NIL_1	Out = NIL, prevent transient instability for fault and trip of a Farrell to Sheffield line, Swamp if less than 3 synchronous West Coast units generating or Farrell 220kV bus coupler open or Hampshire 110kV line is closed.	100	145.24% (374.58)	50.51% (166.85)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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	67	129.13% (273.73)	70.51% (177.38)
V_KIAMSF_DYN	Out = Kiamal Syncon, Limit Kiamal solar farm to 135 MW when Murra Warra 2 WF syncon I/S. Limit Kiamal solar farm to 100 MW when Murra Warra 2 WF syncon O/S	21	100.% (50.)	53.17% (29.76)
NRM_NSW1_VIC1	Negative Residue Management constraint for NSW to VIC flow	43	100.% (9,490)	99.63% (9,275)
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.	85	98.32% (109.77)	13.79% (45.74)
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	15	74.27% (230.57)	32.52% (111.26)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V_KIAMSF_DYN: 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>>V_DDSM_1: 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.

T::T_NIL_1: 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.

NRM_NSW1_VIC1: Investigated and no improvement can be made to the constraint equation at this stage

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

V::N_DDSM_V1: 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 January 2023.

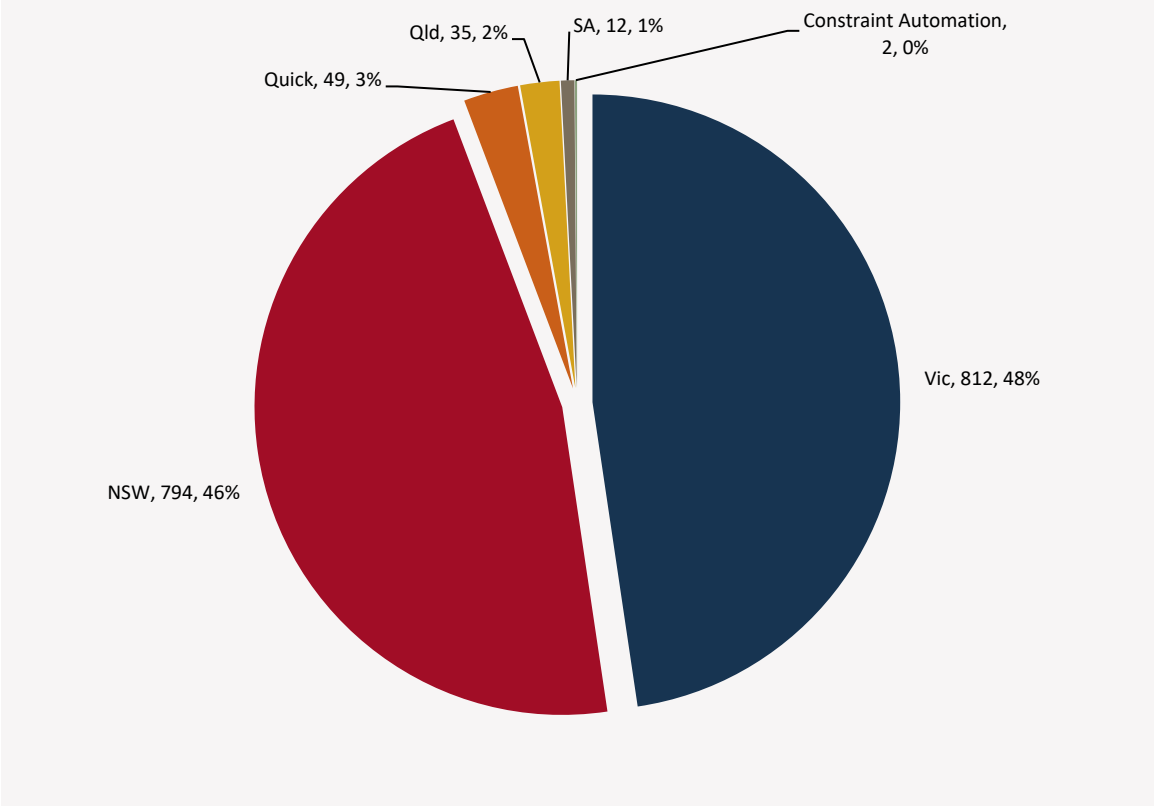
Table 7 Generator and transmission changes

Project	Date	Region	Notes
Cultana – Yadnarie – Port Lincoln No. 1 132kV line	24 January 2023	SA	

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