AEMO

AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

May 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 May 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	7081 (590.08)	Voltage Stability
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	2949 (245.75)	Interconnector Zero
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.	2576 (214.66)	System Strength
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	899 (74.91)	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	759 (63.25)	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	750 (62.5)	Voltage Stability
N^^Q_LS_VC_B1	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	715 (59.58)	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)	579 (48.25)	Discretionary
Q_KEP-HYB_ZERO	Kennedy Energy Park upper limit of 0MW	542 (45.16)	Unit Zero
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	524 (43.66)	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>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1,221,198	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	662,057	Thermal
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	626,988	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	614,668	Voltage Stability
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	545,423	Thermal
N::N_RVYS_2	Out = Ravine – Yass (2), stability limit (Snowy-NSW) for fault at various location between Yass and South Morang area	529,971	Transient 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	491,254	Thermal
S^NIL_PL_MAX	Out = Nil, Maximum generation at Port Lincoln Due to voltage stability limit.	471,545	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)	427,407	Discretionary
V^^V_MLNK_KGTS	Out= Murraylink, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	402,803	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

[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_MOREESF1_23INV	Limit Moree Solar Farm upper limit to 0 MW if number of inverter available exceed 23. Constraint swamp out otherwise.	7 (0.58)	System Strength
NC_Q_KEPWF1	Non Conformance Constraint for KEP WIND	5 (0.41)	Non-Conformance
N_FINLYSF1_0INV	Constraint to violate if Finley solar farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	5 (0.41)	System Strength
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	4 (0.33)	FCAS
S_PPT+SNPT_270	SA Pelican Point + Snapper Point generation <= 270 MW	3 (0.25)	Discretionary
N_GOONSF1_0INV	Constraint to violate if Goonumbla Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	3 (0.25)	System Strength
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
NSA_S_POR03_ISLD	Network Support Agreement for Port Lincoln Unit 3 to meet local islanded demand for the planned outage.	2 (0.16)	Network Support
N_FINLEYSF_49_INV	Limit Finley Solar Farm upper limit to 0 MW if number of inverter available exceed 49. Dispatch only. swamped out if Inverters are within the limit.	2 (0.16)	System Strength
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)	2 (0.16)	Discretionary

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
N_MOREESF1_23INV	Constraint violated for 7 consecutive DIs on 25/05/2022 from 1105 hrs to 1135 hrs with a max violation of 0.48 MW occurring on 25/05/2022 at 1105 hrs. Constraint violated due to Moree Solar Farm exceeding its inverter limit.
NC_Q_KEPWF1	Constraint violated for 5 consecutive DIs on 19/05/2022 from 1010 hrs to 1030 hrs with a max violation of 0.23 MW occurring on 19/05/2022 at 1015 hrs. Constraint violated due to non-conforming of Kennedy Energy Park Wind Farm.
N_FINLYSF1_0INV	Constraint violated for 5 consecutive DIs on 24/05/2022 from 0725 hrs to 0745 hrs with a violation degree of 0.001 MW. Constraint violated due to Finley Solar Farm exceeding its inverter limit.
F_T+NIL_MG_RECL_R6	Constraint violated for 4 DIs with a max violation of 21.56 MW occurring on 31/05/2022 at 1425 hrs. Constraint violated due to the Tasmania raise 6 second availability being lower than the requirement.
S_PPT+SNPT_270	Constraint violated for 3 DIs on 19/05/2022 at 1605 hrs and 1610 hrs and on 23/05/2022 at 1725 hrs with a max violation of 63.65 MW occurring on 19/05/2022 at 1605 hrs. Constraint violated due to Snapper Point non-conforming.

Constraint Equation ID (System Normal Bold)	Description
N_GOONSF1_0INV	Constraint violated for 3 consecutive DIs on 01/05/2022 from 0525 hrs to 0535 hrs with a violation degree of 0.001 MW. Constraint violated due to Goonumbla Solar Farm exceeding its inverter limit. Constraint violated due to Goonumbla Solar Farm exceeding its inverter limit.
NSA_S_POR01_ISLD	Constraint violated for 2 DIs on 31/05/2022 at 0535 hrs and 0540 hrs with a max violation of 7.81 MW occurring on 31/05/2022 at 0540 hrs. Constraint violated due to the start up profile of Port Lincoln Units 1 and 2.
NSA_S_POR03_ISLD	Constraint violated for 2 DIs on 31/05/2022 at 0535 hrs and 0540 hrs with a max violation of 6.97 MW occurring on 31/05/2022 at 0540 hrs. Constraint violated due to the start-up profile of Port Lincoln Unit 3.
N_FINLEYSF_49_INV	Constraint violated for 2 DIs on 26/05/2022 at 1535 hrs and 1540 hrs with a max violation of 5.001 MW occurring on 26/05/2022 at 1535 hrs. Constraint violated due to Finley Solar Farm exceeding its inverter limit.
S_ISLE_LKB1+2+3_60	Constraint violated for 2 DIs on 16/05/2022 at 0635 hrs and 0640 hrs with a max violation of 2.52 MW occurring on 16/05/2022 at 0640 hrs. Constraint violated due to Lake Bonney Wind Farm non-conforming.

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	6745 (562.08)	-71.47 (31.26)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	2740 (228.33)	0.0 (0.0)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1470 (122.5)	255.21 (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	777 (64.75)	242.26 (439.01)
N^^Q_LS_VC_B1	NSW1-QLD1 Export	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	715 (59.58)	230.43 (485.64)
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	637 (53.08)	359.73 (1189.43)
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	582 (48.5)	-21.8 (-439.0)
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	495 (41.25)	151.17 (173.83)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	466 (38.83)	178.66 (439.01)
N::N_RVYS_2	VIC1-NSW1 Export	Out = Ravine – Yass (2), stability limit (Snowy-NSW) for fault at various location between Yass and South Morang area	437 (36.42)	16.97 (1008.59)

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_51934522	15/05/2022 18:30 to 15/05/2022 20:00	To avoid overloading the Ballarat – Bendigo 220 kV line on trip of the Horsham – Murra Warra – Kiamal SF 220 kV line.
CA_SYDS_51A7040E	30/05/2022 17:55 to 30/05/2022 20:10	To avoid overloading the Crookwell WF – Bannaby 330 kV (61) line on trip of Marulan – Collector WF 330 kV (04) line or Marulan – Yass 330 kV (18) line.

2.5.1 Further Investigation

CA_BRIS_51934522: The following constraint equations where created on 16/05/2022 to avoid overloading the Ballarat to Bendigo 220kV line on trip of Kiamal to Red Cliffs 220kV line: V>>V_NIL_25, V>>V_NIL_25_1, V>>V_NIL_26, V>>V_NIL_26_1, V>>V_NIL_26A, V>>V_NIL_26A_1, V>>V_KM_CB_2, V>>KM_CB_2_1.

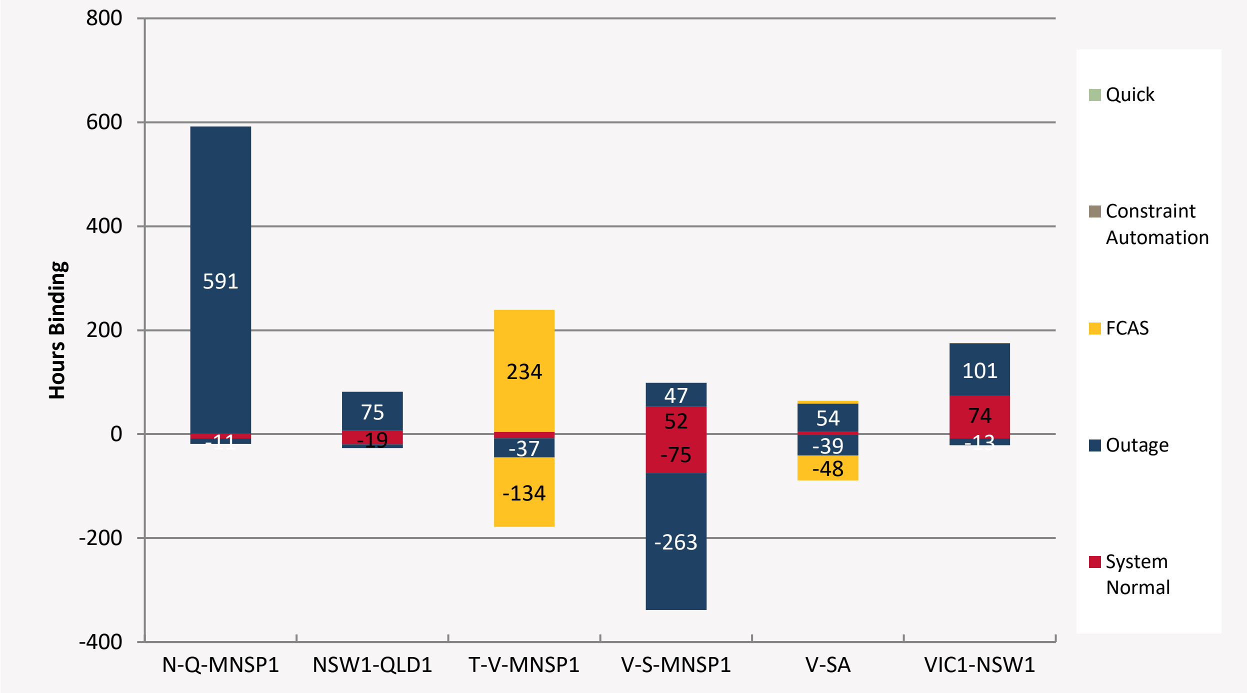
CA_SYDS_51A7040E: A new constraint equation (N>>N-DTKV_CTMN) was create on 31/05/2022 to avoid overloading the Crookwell – Bannaby 330 kV (61) line on trip of the Collector WF – Marulan 330 kV (04) line during outage of Dapto – Kangaroo Valley 330 kV (18) line.

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.

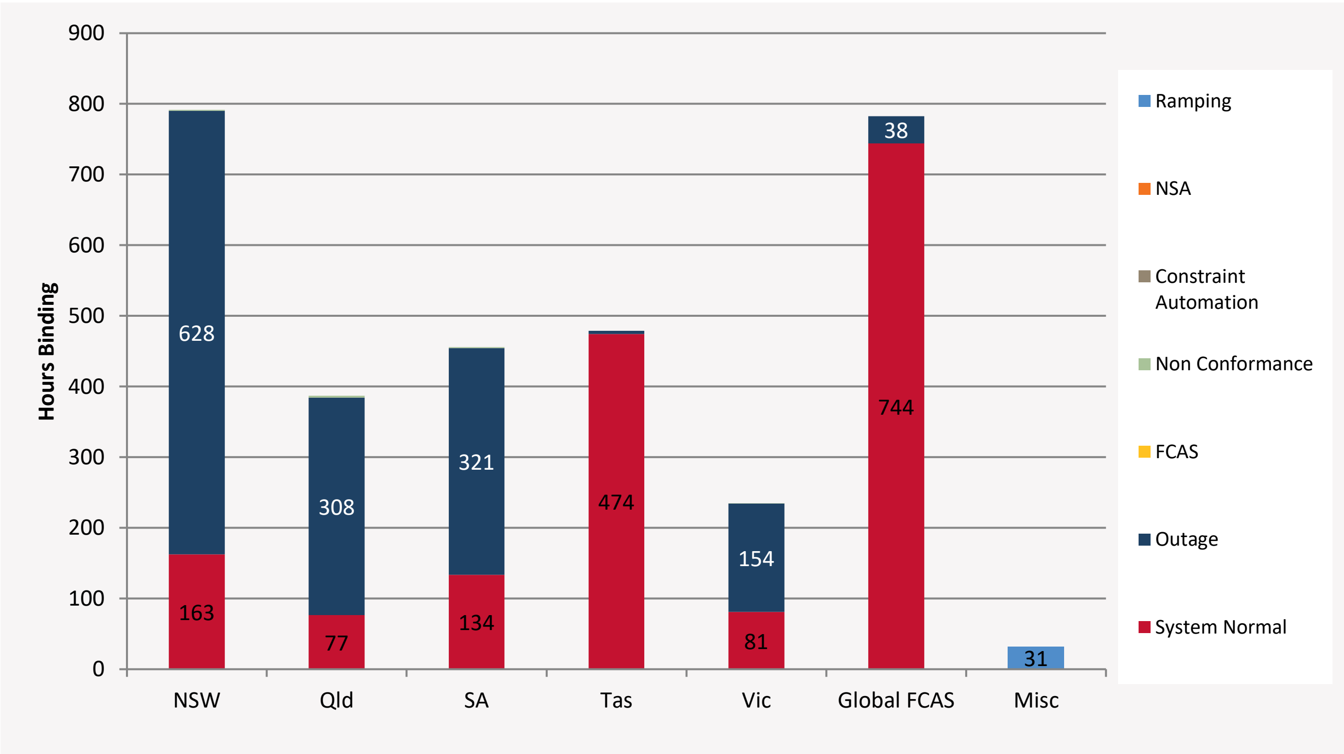
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

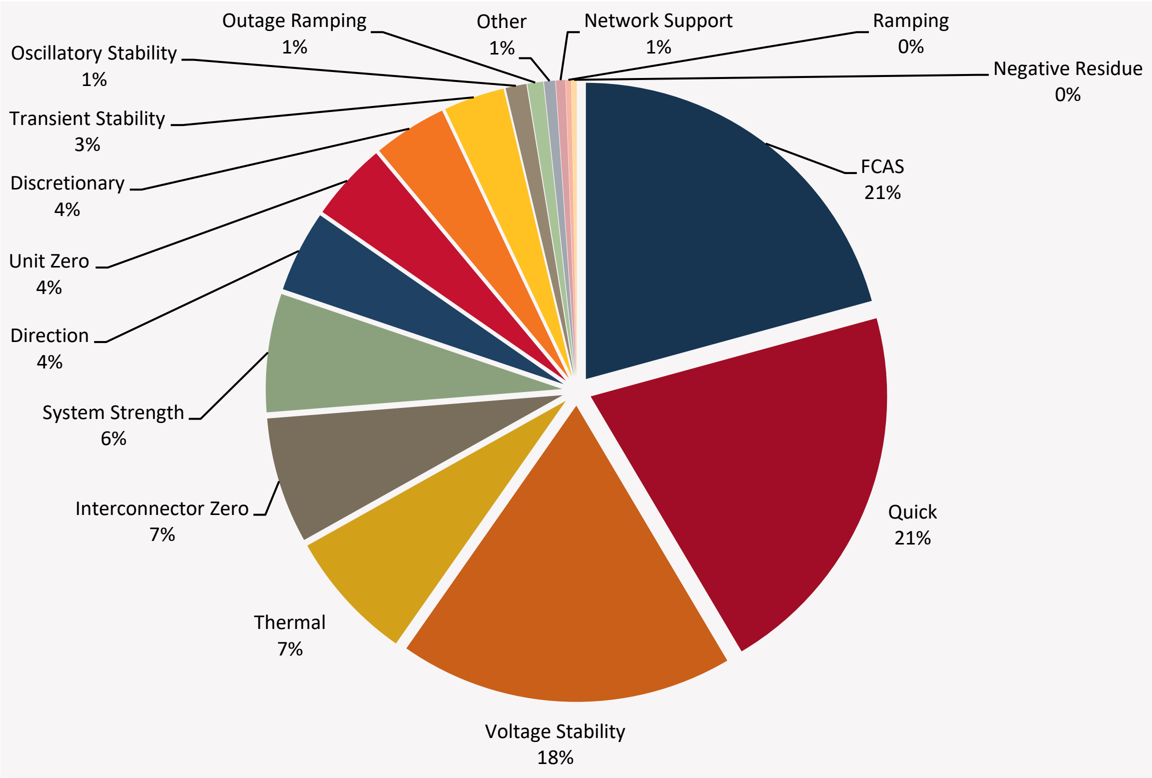
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

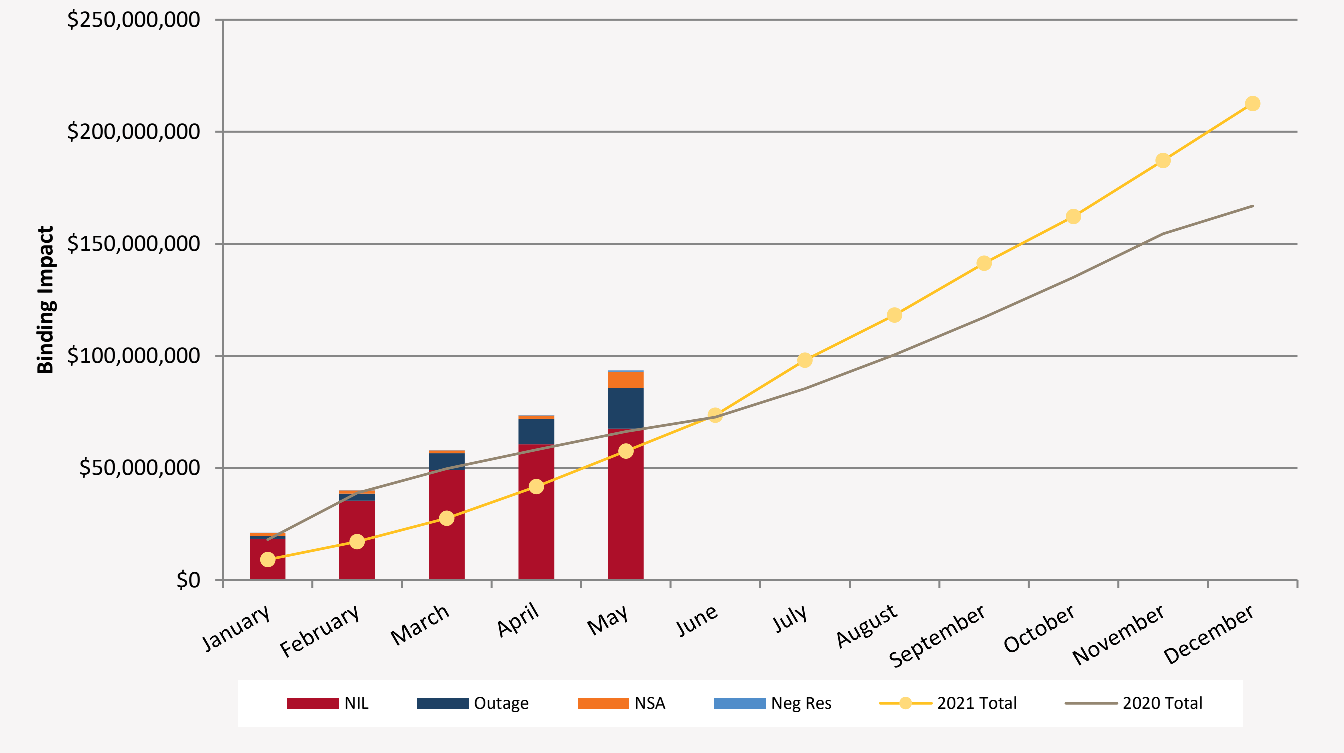
Figure 3 Binding by limit type



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	1266	133,919% (107.13)	370% (21.71)
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.	37	22,129% (373.88)	842% (173.68)
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.	60	18,589% (282.9)	903% (128.38)
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.	58	9,099% (275.26)	536% (119.13)

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.	35	3,647% (304.45)	379% (152.39)
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	64	1,922% (244.65)	125.39% (105.98)
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.	21	1,638% (9,425)	767% (4,501)
V::N_SMF2_O2	Out = South Morang F2 500/330kV txfmr, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 500kV.	5	580% (290.52)	273% (203.96)
V::N_DDSM_V2	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 500 kV.	64	408% (233.42)	66.63% (73.79)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V>>V_DDSM_1: Investigated in June 2022 and no improvements can be made to the constraint equation at this stage.

NSA_S_POR01_ISLD: Investigated in June 2022 and no improvements can be made to the constraint equation at this stage.

N^N-LS_SVC: Investigated in May 2022 and no improvement can be made to the constraint equation at this stage.

V::N_X_SMSC_O1: Investigated in May 2022 and no improvement can be made to the constraint equation at this stage.

V::N_X_SMSC_V1: Investigated in May 2022 and no improvement can be made to the constraint equation at this stage.

V::N_X_SMSC_V2: Investigated in May 2022 and no improvement can be made to the constraint equation at this stage.

V::N_X_SMSC_O2: Investigated in May 2022 and no improvement can be made to the constraint equation at this stage.

V_S_HEYWOOD_UFLS: Investigated in May 2022 and no improvement can be made to the constraint equation at this stage. Changes to the status of the reactive devices between DS/PD contributes to the PD accuracy.

V::N_DDSM_V2: Investigated in May 2022 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 May 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Temporary Generation South Lonsdale	1 May 2022	SA	Deregistered Generator
Demand Response – Enel X NSW 36	17 May 2022	NSW	New registration for Wholesale Demand Response
Woolooga Solar Farm	24 May 2022	Qld	New Generator

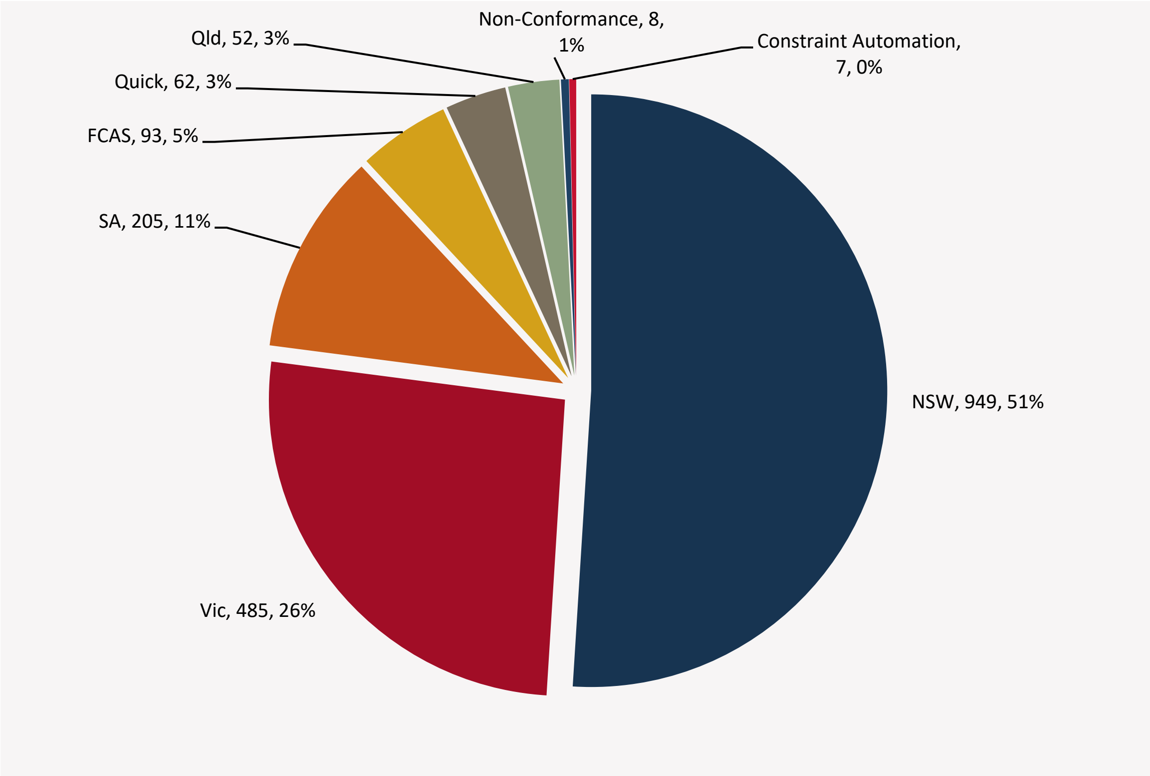
3.1 Constraint Equation Changes

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