Monthly Constraint Report

November 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 November 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_TARALGAWF_ZERO	Taralga WF upper limit of 0 MW	6813 (567.75)	Unit Zero
T>T_X_NTH_STH_B	Out = Credible risk of, or actual, Tas Nth-Sth separation. Limit southern generators to >= southern load - 15 MW	6090 (507.5)	Thermal
T_MRWF_100	Discretionary 100 MW upper limit on Musselroe Wind Farm	2898 (241.5)	Discretionary
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2796 (233.0)	Thermal
N::N_UTRV_2	Out = Ravine -Yass(2) 330kV line outage or Upper Tumut to Ravine (6X) 330kV line O/S, stability limit (Snowy-NSW) for fault at various location between Yass and South Morang area	2143 (178.58)	Transient Stability
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	2136 (178.0)	Thermal
T_NTH_ROCOF_1	Out = Credible risk of, or actual, Tas Nth-Sth separation. Limit non-synchronous generation and Basslink import to limit instantaneous Rate of Change of Frequency to < 3 Hz/sec in Nth TAS	2135 (177.91)	ROC Frequency
T_CTHLWF_100	Wild Cattle Hill Wind Farm upper limit of 100 MW	2107 (175.58)	Discretionary
SA_TBSE1	SA / Eastern separation between Tailem Bend and South East (TBSS - SESS) Vic-SA Flow = South East Area Load - Local Generation	2038 (169.83)	Region Separation
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1913 (159.41)	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
F_S+LREG_0035	SA Lower Regulation FCAS Requirement greater than 35 MW	3,915,973	FCAS
F_S+RREG_0035	SA Raise Regulation FCAS Requirement greater than 35 MW	2,758,587	FCAS
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2,611,552	Thermal
F_S+OD_TL_L60	Lower 60 sec Service Requirement for SA island for loss of Olympic Dam	2,394,364	FCAS
SA_TBSE1	SA / Eastern separation between Tailem Bend and South East (TBSS - SESS) Vic-SA Flow = South East Area Load - Local Generation	2,160,081	Region Separation
F_S_HPRL_LREG-5MW	Out= NIL, Hornsdale Battery (Load Component) LREG Requirement <= 5MW	2,010,071	FCAS
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1,565,448	Thermal
N_TARALGAWF_ZERO	Taralga WF upper limit of 0 MW	1,532,695	Unit Zero
F_S_HPRG_RREG-5MW	Out= NIL, Hornsdale Battery (Generation Component) RREG Requirement <= 5MW	1,362,902	FCAS
S>>BWMP_TWPA_TPRS	Out= Blyth West- Munno Para 275kV line with Blyth West CB8002 OPEN, avoid O/L Templers-Roseworthy 132kV line on trip of Templers West-Para 275kV line, Feedback	1,274,699	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 (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
F_S+LREG_0035	SA Lower Regulation FCAS Requirement greater than 35 MW	79 (6.58)	FCAS
F_S+RREG_0035	SA Raise Regulation FCAS Requirement greater than 35 MW	47 (3.91)	FCAS
F_S+TB2_R60_70M	Raise 60 sec Service Requirement for SA island for loss of Torrens Island B2 for 70 MW metro gen trip option	41 (3.41)	FCAS
F_S+TB4_R60_70M	Raise 60 sec Service Requirement for SA island for loss of Torrens Island B4 for 70 MW metro gen trip option	41 (3.41)	FCAS
S_TIPSB4+PV_180	Upper limit for TIPSB4 +SA rooftop PV trip <=180 MW for 70 MW metro gen option for SA Island - see TOA447	32 (2.66)	Discretionary
S_TIPSB2+PV_180	Upper limit for TIPSB2 +SA rooftop PV trip <=180 MW for 70 MW metro gen option for SA Island - see TOA447	30 (2.5)	Discretionary
F_T+STH_NYR_ML_L6	Lower 6 sec requirement for South Tasmania for loss of Nyrstar load	27 (2.25)	FCAS
F_S+TB2_R5_70M	Raise 5 min Service Requirement for SA island for loss of Torrens Island B2 for 70 MW metro gen trip option	24 (2.0)	FCAS
F_S+TB4_R5_70M	Raise 5 min Service Requirement for SA island for loss of Torrens Island B4 for 70 MW metro gen trip option	24 (2.0)	FCAS
T_GO1_100	Discretionary 100 MW upper limit on Gordon unit 1	22 (1.83)	Discretionary

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_S+LREG_0035	The constraint equation violated for 79 non-consecutive DIs from 13/11/2022 0800 hrs to 19/11/2022 0555 hrs with a max violation of 33 MW occurring at at 15/11/2022 1620 hrs and 19/11/2022 0550 hrs. Constraint equation violated due to South Australia lower regulation service availability less than requirement.
F_S+RREG_0035	The constraint equation violated for 47 non-consecutive DIs from 13/11/2022 0310 hrs to 19/11/2022 0555 hrs with a max violation of 30 MW occurring at 15/11/2022 1620 hrs. Constraint equation violated due to South Australia raise regulation service availability less than requirement.
F_S+TB2_R60_70M	The constraint equation violated for 41 non-consecutive DIs from 17/11/2022 0905 hrs to 19/11/2022 0955 hrs with a max violation of 22.73 MW occurring at 17/11/2022 1010 hrs. Constraint equation violated due to South Australia 60 second raise service availability less than requirement.
F_S+TB4_R60_70M	The constraint equation violated for 41 non-consecutive DIs from 17/11/2022 0905 hrs to 19/11/2022 0955 hrs with a max violation of 22.73 MW occurring at 17/11/2022 1010 hrs. Constraint equation violated due to South Australia 60 second raise service availability less than requirement.
S_TIPSB4+PV_180	The constraint equation violated for 32 non-consecutive DIs from 17/11/2022 0925 hrs to 19/11/2022 1010 hrs with a max violation of 10 MW occurring at 19/11/2022 0850 hrs, 0855 hrs, 0900 hrs, 0905hrs and 0915 hrs. Constraint equation violated due to Torrens Island B4 + SA rooftop PV output exceeding its upper limit of 180 MW.
S_TIPSB2+PV_180	The constraint equation violated for 30 non-consecutive DIs from 17/11/2022 0925 hrs to 19/11/2022 1005 hrs with a max violation of 10 MW occurring at 19/11/2022 from 0850hrs to 0915hrs. Constraint equation violated due to Torrens Island B2 + SA rooftop PV output exceeding its upper limit of 180 MW.

Constraint Equation ID (System Normal Bold)	Description
F_T+STH_NYR_ML_L6	The constraint equation violated 27 non-consecutive DIs with a max violation of 17.8 MW occurring at 05/11/2022 1410 hrs. Constraint violated due to South Tasmania lower 6 second availability being less than the requirement.
F_S+TB2_R5_70M	The constraint equation violated for 24 consecutive DIs from 17/11/2022 0915 hrs to 1110 hrs with a max violation of 24.73 MW occurring at 17/11/2022 1010 hrs. Constraint equation violated due to South Australia raise 5 min service availability less than requirement.
F_S+TB4_R5_70M	The constraint equation violated for 24 consecutive DIs from 17/11/2022 0915 hrs to 1110 hrs with a max violation of 24.73 MW occurring at 17/11/2022 1010 hrs. Constraint equation violated due to South Australia raise 5 min service availability less than requirement.
T_GO1_100	The constraint equation violated 22 non-consecutive DIs from 15/11/2022 0245 hrs to 22/11/2022 0130 hrs with a max violation of 59.35 MW occurring at 22/11/2022 0130 hrs. Constraint equation violated due to Gordon Unit 1 exceeding its upper limit of 100 MW.

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)
T_NTH_ROCOF_1	T-V-MNSP1 Import	Out = Credible risk of, or actual, Tas Nth-Sth separation. Limit non-synchronous generation and Basslink import to limit instantaneous Rate of Change of Frequency to < 3 Hz/sec in Nth TAS	1923 (160.25)	-208.85 (-399.35)
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	1851 (154.25)	-28.72 (95.95)
N::N_UTRV_2	VIC1-NSW1 Export	Out = Ravine -Yass(2) 330kV line outage or Upper Tumut to Ravine (6X) 330kV line O/S, stability limit (Snowy-NSW) for fault at various location between Yass and South Morang area	1850 (154.17)	301.52 (1167.19)
SA_TBSE1	V-SA Export	SA / Eastern separation between Tailem Bend and South East (TBSS - SESS) Vic-SA Flow = South East Area Load - Local Generation	1664 (138.67)	22.97 (105.02)
N_X_MBTE_3A	N-Q-MNSP1 Export	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	1589 (132.42)	-22.51 (11.3)
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	1515 (126.25)	162.01 (193.48)
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	1322 (110.17)	96.4 (1071.49)
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	843 (70.25)	-93.15 (-409.04)
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	773 (64.42)	143.06 (-177.33)
SVML^NIL_MH-CAP_ON	V-S-MNSP1 Import	Out=NIL, SA to Vic on ML upper transfer limit to manage voltage collapse at Monash (Note: applies when capacitor banks at Monash are available and I/S for switching.)	641 (53.42)	-158.23 (-185.76)

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_5283EFAB	14/11/2022 07:45 to 14/11/2022 14:20	CA was created to manage overloading of New Norfolk to Creek Road for loss of Chapel Street – New Norfolk + Nyrstar load and vice versa.

2.5.1 Further Investigation

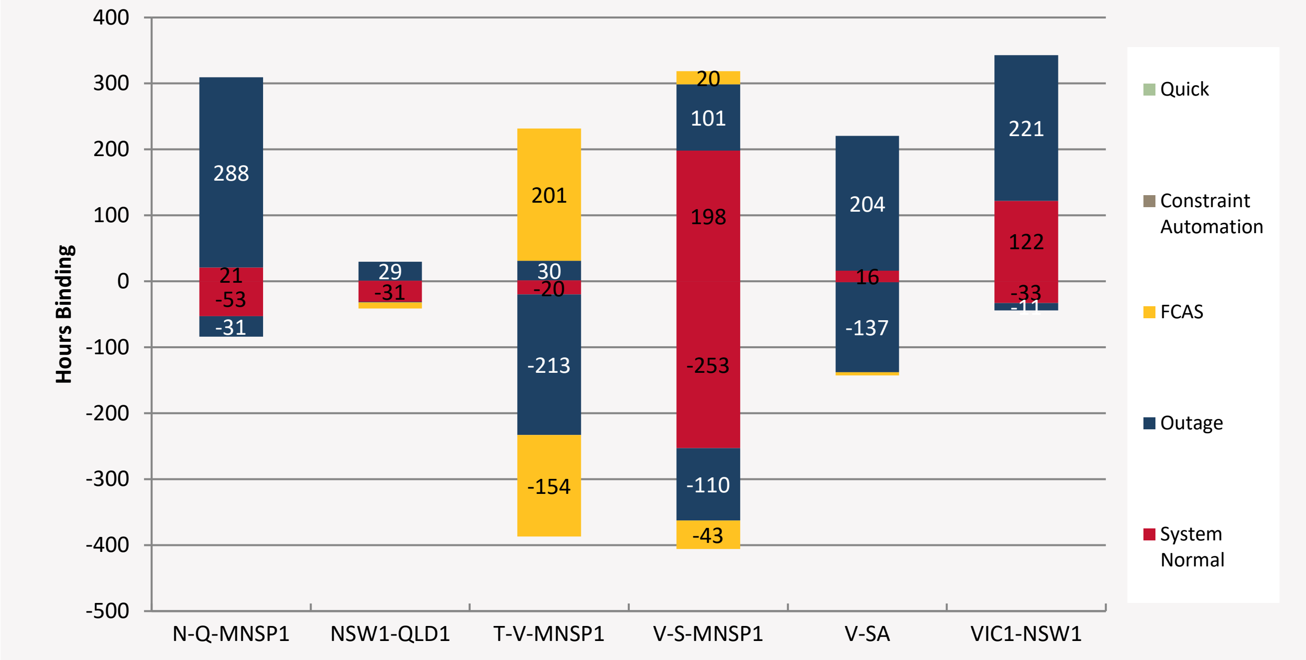
CA_SYDS_5283EFAB: Constraint equation T>T_X_LIPM_TWO_F was created to replace CA_SYDS_5283EFAB and was added to the set T-X_LIPM on 14/11/22.

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.

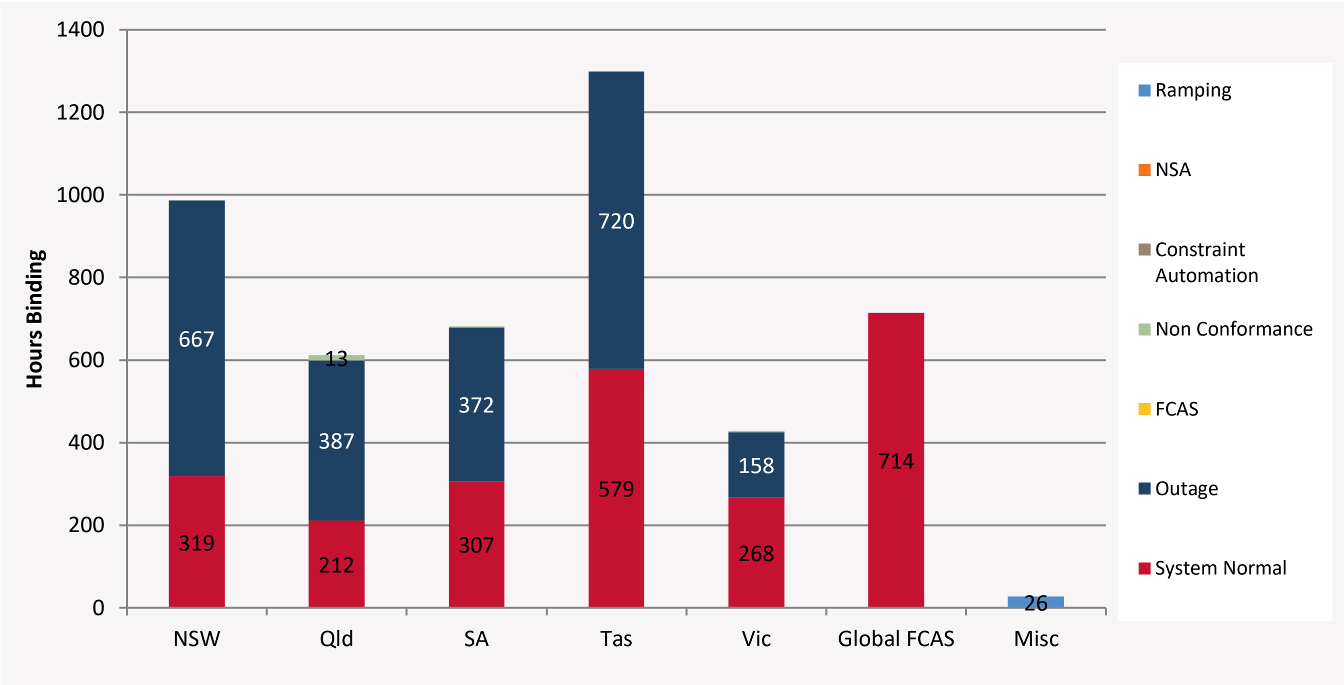
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

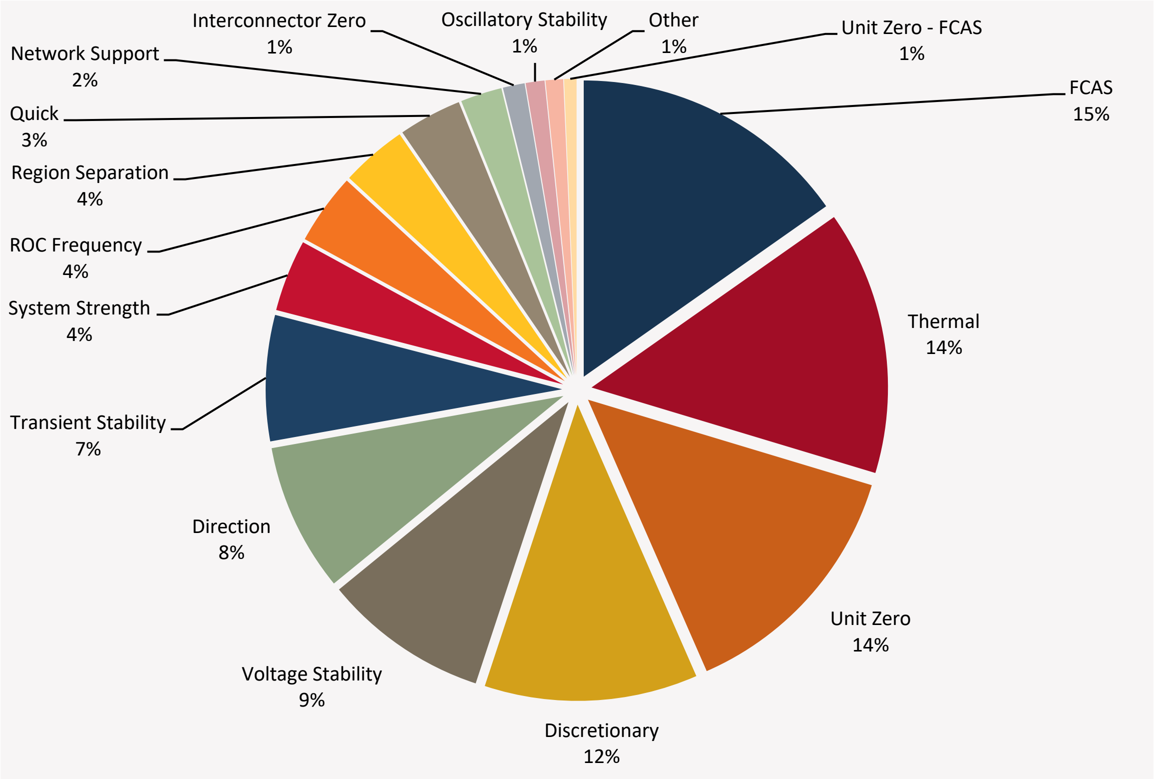
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

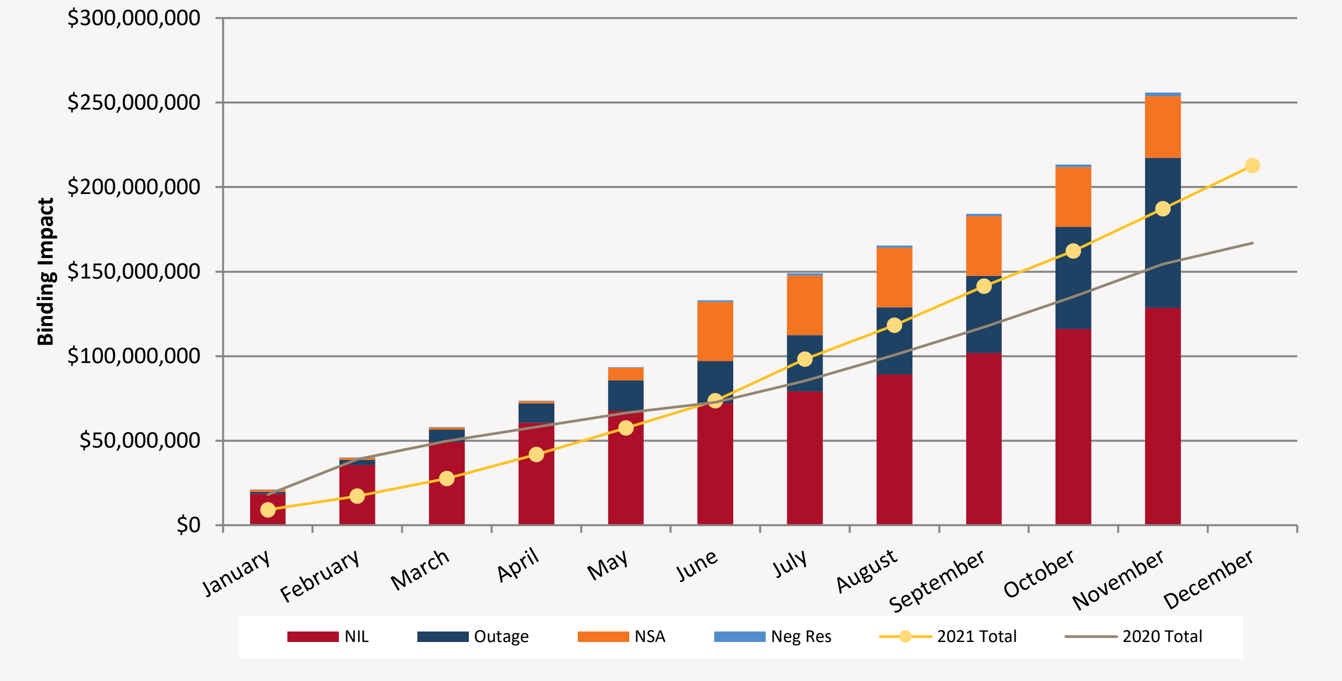
Figure 3 Binding by limit type



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	437	28,958% (133.38)	336% (29.61)
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.	17	10,186% (178.65)	798% (85.48)
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.	17	9,785% (167.65)	706% (47.77)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	78	3,520% (35.2)	231% (10.32)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	280	3,520% (35.2)	93.93% (8.03)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_ESTN_TBSE_O1	SA / ESTN separation between Tailem Bend and South East Sub, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, Other than VIC accelerates. Yallourn W G1 on 220kV.	29	2,049% (234.55)	259% (110.72)
V::N_ESTN_TBSE_VE	SA / ESTN separation between Tailem Bend and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 2	46	1,695% (519)	148.35% (144.98)
V::S_HYSE_MAXG_2	Out =One Heywood-South East 275kV line O/S (Note: with both Black Range series caps O/S); Vic to SA Transient Stability limit for loss of the largest generation block in SA.	7	652% (130.11)	197% (78.02)
V::N_ESTN_TBSE_VD	SA / ESTN separation between Tailem Bend and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 1	26	507% (519)	138.77% (137.59)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_ESTN_TBSE_O1: Investigated and no improvement can be made to the constraint equation at this stage.**V::N_ESTN_TBSE_VE:** Investigated and the constraint is being archived from the system.

V::S_HYSE_MAXG_2: Investigated and no improvement can be made to the constraint equation at this stage

T_WIND_NTH_100: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_ESTN_TBSE_VD: Investigated and the constraint is being archived from the system.

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

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

V::N_X_SMSC_V1: 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.

N_X_MBTE_3A: 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.

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 November 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Narrandera Substation	27 November 2022	NSW	Narrandera substation has been cut in between the existing Yanco – Uranquinty 99F 132kV line.
Bolivar Power Station (128 Mw)	29 November 2022	SA	New Generator
Berrybank 2 Wind Farm	29 November 2022	Victoria	New Generator

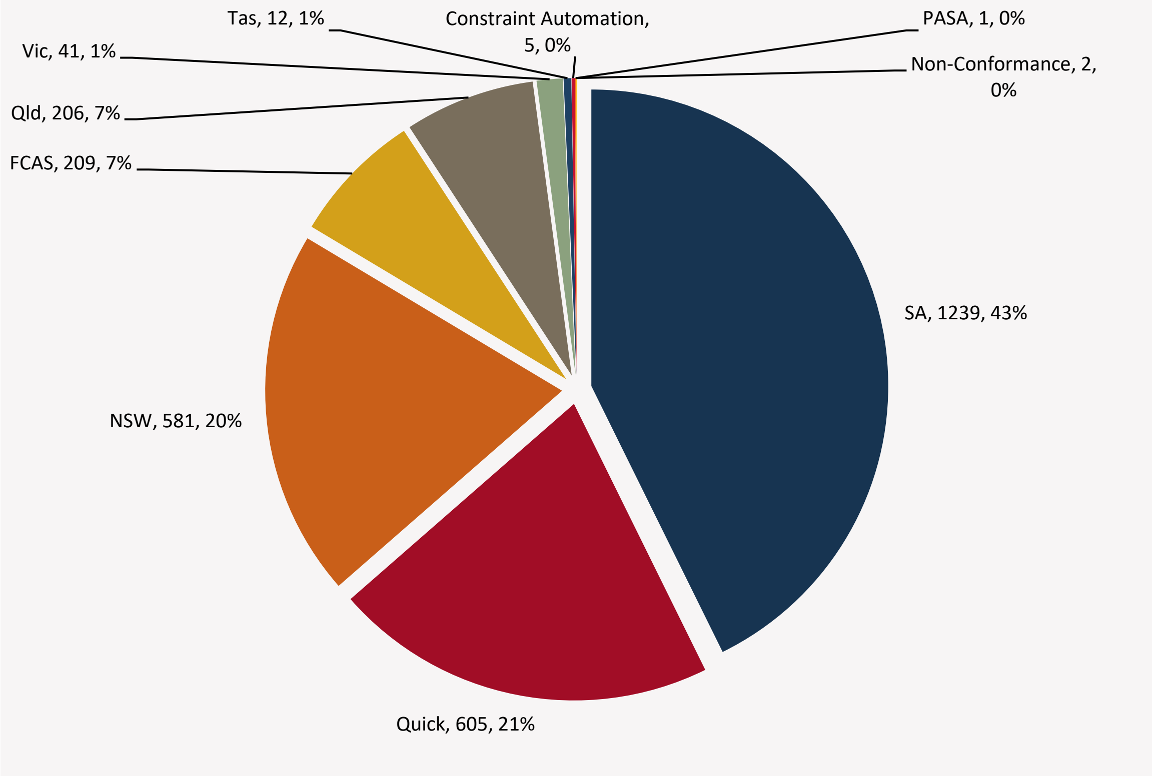
3.1 Constraint Equation Changes

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