AEMO

AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

December 2022

A report for the National Electricity Market on Constraint results.

AEMO

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 December 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_005	Taralga WF upper limit of 5 MW	4319 (359.91)	Discretionary
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	3135 (261.25)	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	2876 (239.66)	Voltage Stability
Q_KEP-HYB_25MW	Kennedy Energy Park upper limit of 25MW	2532 (211.0)	Discretionary
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	2467 (205.58)	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	2380 (198.33)	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	2281 (190.08)	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	2280 (190.0)	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	2277 (189.75)	Voltage Stability
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1776 (148.0)	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	4,020,622	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	2,263,270	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	2,058,356	Voltage Stability
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1,948,792	Thermal
N_TARALGAWF_005	Taralga WF upper limit of 5 MW	1,676,591	Discretionary
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	1,674,547	Thermal
N>NIL_9R6_9R5	Out= Nil, avoid O/L Wagga North to Wagga132 (9R6) on trip of Wagga North to Wagga330 (9R5) line, Feedback	1,420,422	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	1,400,898	Thermal
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	1,153,272	Voltage Stability
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	1,128,220	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
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	19 (1.58)	System Strength
V_KIAMSF_40INV	Limit Kiamal Solar Farm upper limit to 0 MW if number of inverter available exceeds 40. Constraint swamps out otherwise. DS only	10 (0.83)	System Strength
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	6 (0.5)	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	6 (0.5)	FCAS
NC_S_BOWWPV1	Non Conformance Constraint for BOLIVAR WWTP PV1	6 (0.5)	Non-Conformance
V_GANWR_BAT_L_ISL_0	Gannawarra Battery (Load Component) upper limit of 0 MW to manage risk of islanding on the next contingency	4 (0.33)	Islanding - Unit
V_GANWRSF_0INV	Constraint to violate if Gannawarra Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	4 (0.33)	System Strength
V_COHUNASF_0INV	Constraint to violate if Cohuna Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	4 (0.33)	System Strength
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+NIL_ML_L6	Out = Nil, Lower 6 sec requirement for a Tasmania Load Event, Basslink unable to transfer FCAS	3 (0.25)	FCAS

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 19 consecutive DIs on 20/12/2022 0620 hrs to 0750 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Kiamal Solar Farm exceeding its inverter limit when Murrawarra synchronous condenser was out of service
V_KIAMSF_40INV	The constraint equation violated for 10 non-consecutive DIs from 10/12/2022 0530 hrs to 16/12/2022 1040 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Kiamal Solar Farm exceeding its inverter limit.
F_T+NIL_WF_TG_R6	The constraint equation violated for 6 non-consecutive DIs from 07/12/2022 1050 hrs to 14/12/2022 1040 hrs with a max violation of 17.88 MW occurring at 07/12/2022 1055 hrs. 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 6 non-consecutive DIs from 04/12/2022 1125 hrs with 15/12/2022 1600 hrs with a max violation of 5.72 MW occurring at 04/12/2022 1135 hrs. Constraint equation violated due to the Tasmania raise 6 secs availability being lower than the requirement.
NC_S_BOWWPV1	The constraint equation violated for 6 consecutive DIs on 11/12/2022 from 1205 hrs to 1250 hrs with a max violation of 0.14 MW occurring at 1220 hrs. Constraint violated due to Bolivar WWTP PV1 non-conforming.
V_GANWR_BAT_L_ISL_0	The constraint equation violated for 4 consecutive DIs on 11/12/2022 from 1215 hrs to 1230 hrs with a max violation of 0.35 MW occurring at 1220 hrs. Constraint violated due to Gannawarra Battery load component exceeding its upper limit of 0 MW.
V_GANWRSF_0INV	The constraint equation violated for 4 consecutive DIs on 11/12/2022 from 1215 hrs to 1230 hrs with a max violation degree of 0.001 MW. Constraint violated due to Gannawarra Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
V_COHUNASF_0INV	The constraint equation violated for 4 consecutive DIs on 11/12/2022 from 1215 hrs to 1230 hrs with a max violation degree of 0.001 MW. Constraint equation violated due to Cohuna Solar Farm exceeding its inverter limit.
F_T_AUFLS2_R6	The constraint equation violated for 3 non-consecutive DIs from 05/12/2022 0150 hrs to 15/12/2022 0725 hrs with a max violation of 17.63 MW occurring at 15/12/2022 0725 hrs. The constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
F_T+NIL_ML_L6	The constraint equation violated for 3 consecutive DIs on 13/12/2022 from 1115 hrs to 1125 hrs with a max violation of 5.62 MW occurring at 1120 hrs. Constraint equation violation occurred due to the Tasmania lower 6 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_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	2521 (210.08)	217.38 (1111.24)
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	2269 (189.08)	-30.69 (96.49)
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	2058 (171.5)	167.33 (202.39)
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	1787 (148.92)	152.55 (-130.04)
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	1602 (133.5)	-405.48 (-462.0)
N_X_MBTE_3A	N-Q-MNSP1 Export	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	1538 (128.17)	-36.13 (10.0)
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	1518 (126.5)	-370.05 (-462.0)
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	1260 (105.0)	-396.2 (-462.0)
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	1235 (102.92)	145.21 (-161.64)
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	1035 (86.25)	164.57 (200.93)

2.5 Constraint Automation Usage

The constraint automation is an application in AEMO's energy management system (EMS) which generates thermal overload constraint equations based on the current or planned state of the power system. It is currently used by on-line staff to create thermal overload constraint equations for power system conditions where there were no existing constraint equations or the existing constraint equations did not operate correctly.

The following section details the reason for each invocation of the non-real time constraint automation constraint sets and the results of AEMO's investigation into each case.

Non-real time constraint automation was not used.

2.5.1 Further Investigation

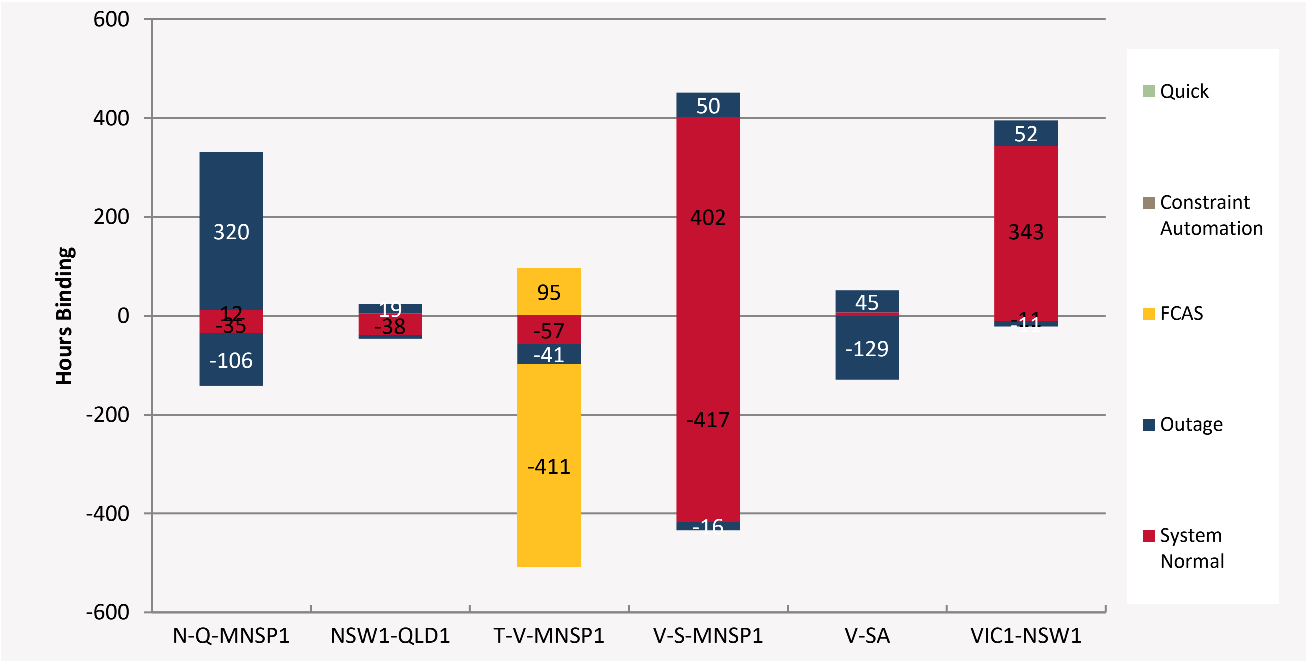
Non-real time constraint automation was not used.

2.6 Binding Dispatch Hours

This section examines the number of hours of binding constraint equations on each interconnector and by region. The results are further categorized into five types: system normal, outage, FCAS (both outage and system normal), constraint automation and quick constraints.

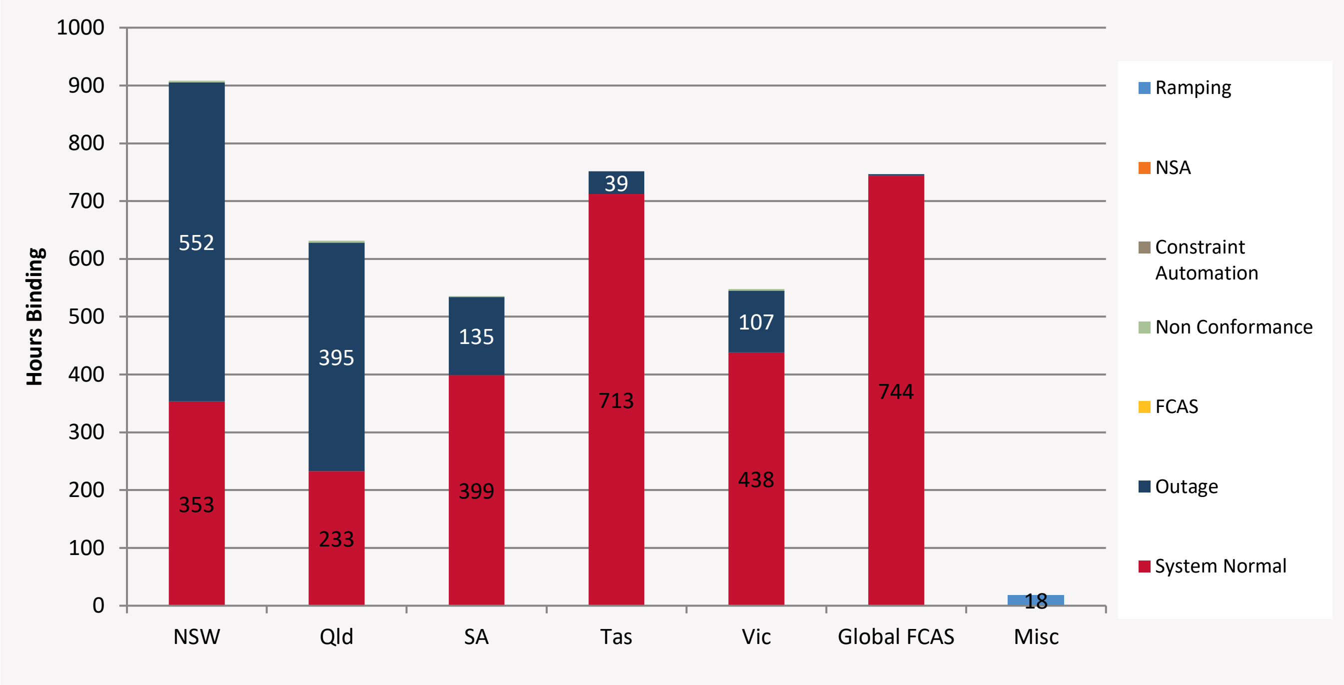
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

Figure 1 Interconnector binding dispatch hours



The regional comparison graph below uses the same categories as in Figure 1 as well as non-conformance, network support agreement and ramping. Constraint equations that cross a region boundary are allocated to the sending end region. Global FCAS covers both global and mainland requirements.

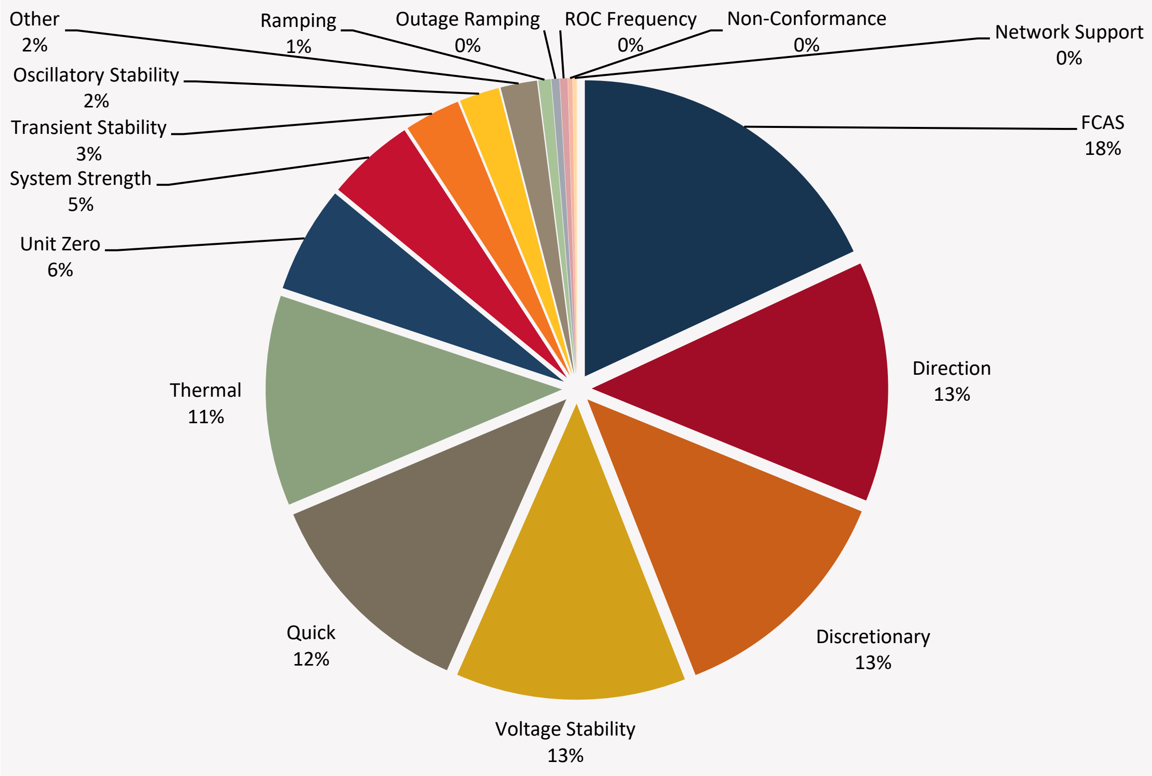
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

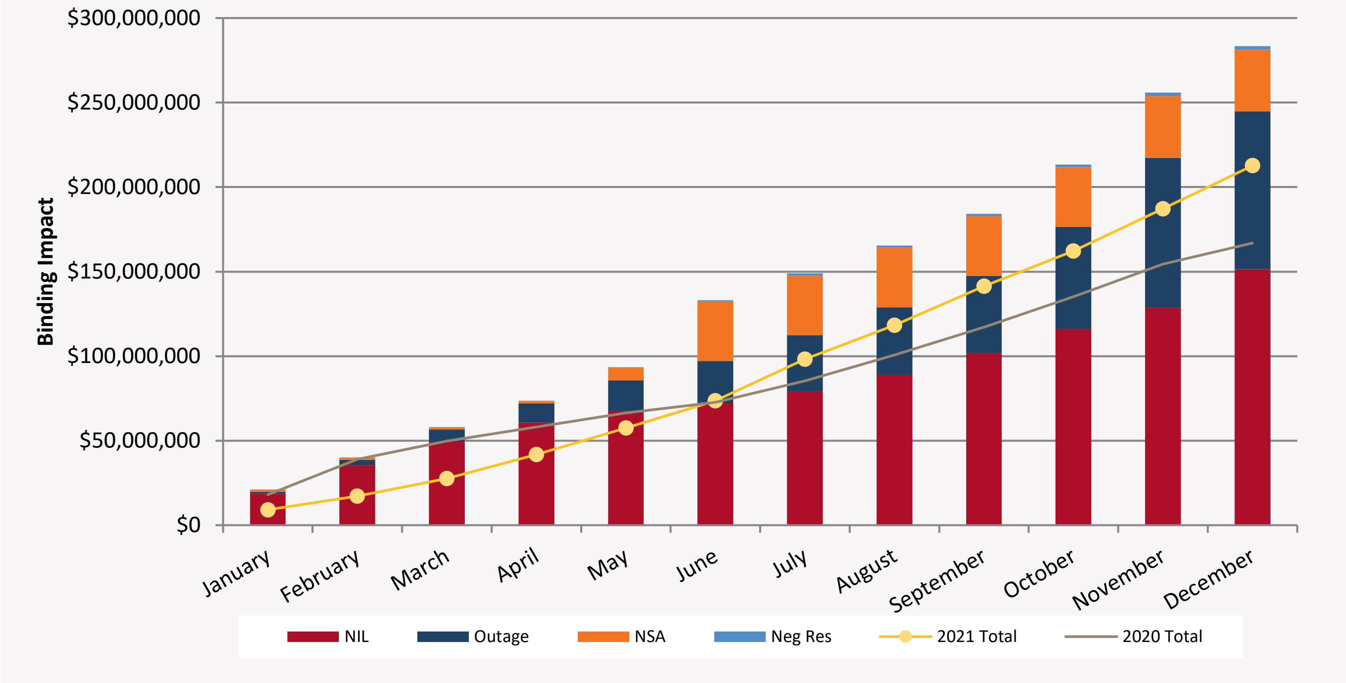
Figure 3 Binding by limit type



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	543	34,956% (104.54)	208% (26.58)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	150	3,660% (36.6)	121.28% (9.11)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	283	3,660% (43.2)	77.37% (8.07)
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.	41	238% (172.)	29.1% (70.72)
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.	154	194% (365.79)	45.78% (119.47)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	108	114.81% (164.82)	14.22% (46.78)
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	17	104.47% (244.03)	71.33% (182.77)
V_KIAMSF_DYN	Out = Kiamal Syncon, Limit Kiamal solar farm to 100 MW when Murra Warra 2 WF syncon I/S. Limit Kiamal solar farm to 50 MW when Murra Warra 2 WF syncon O/S	9	100.% (50.)	100.% (50.)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	193	64.61% (335.26)	10.17% (41.68)

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.

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.

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

T::T_NIL_1: 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^^SML_NSWRB_2: Investigated and no improvement can be made to the constraint equation at this stage.

T_ROCOF_3: Investigated and the mismatch is due to the calculation of Tasmanian inertia in PD. Currently testing options to improve the Tas inertia in Predispatch.

V_T_NIL_FCSPS: This constraint equation uses analog values for the load enabled for the FCSPS in Pre-dispatch. This value can change quickly in dispatch and this is not possible to predict in Pre-dispatch. No changes proposed.

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 December 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Edenvale Solar Farm	20 December 2022	Qld	New Generator
New England Solar Farm #2	20 December 2022	NSW	New Generator
New England Solar Farm #1	20 December 2022	NSW	New Generator

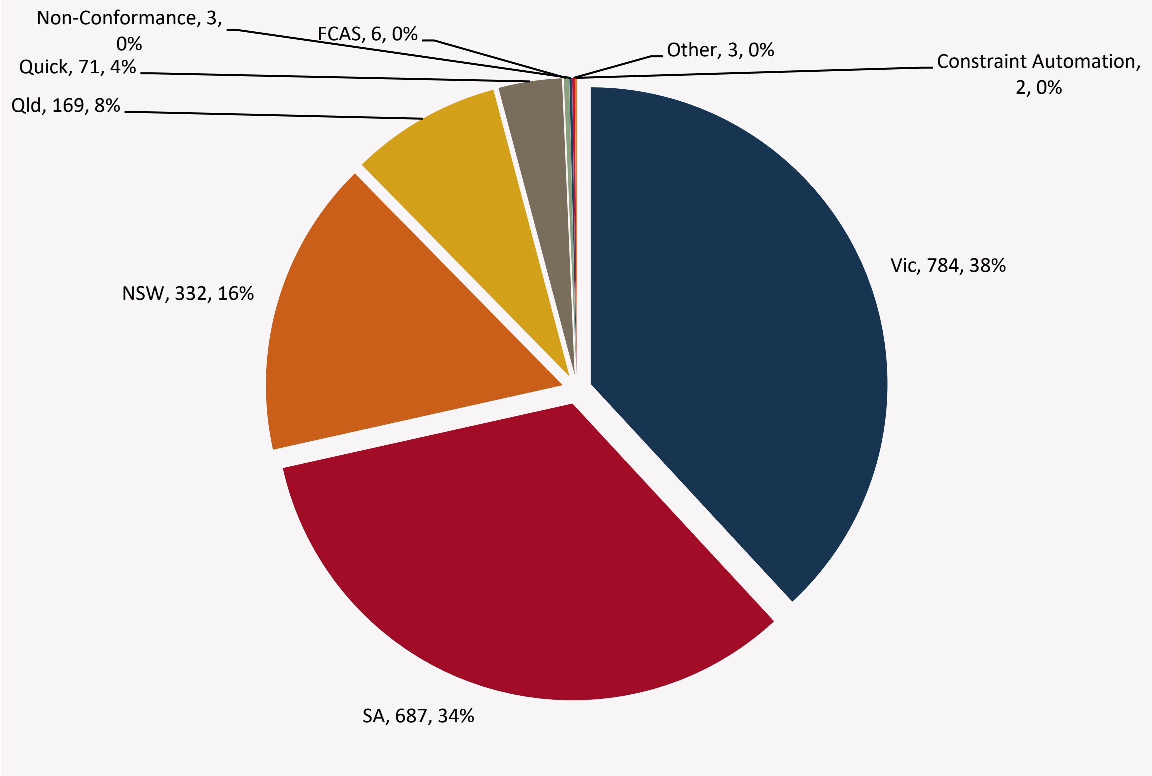
3.1 Constraint Equation Changes

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