Monthly Constraint Report

October 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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1 Introduction

This report details constraint equation performance and transmission congestion related issues for October 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^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	3330 (277.5)	Voltage Stability
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2723 (226.91)	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 [Note: swamped with 96M or 9UJ or 9UH is O/S]	2436 (203.0)	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1915 (159.58)	Thermal
S_WATERLWF_RB	Out= Nil, Limit Waterloo WF output to its runback MW capability, DS only	1530 (127.5)	Discretionary
V_CWWF_FLT_0	Limit Crowlands Wind Farm upper limit to 0 MW to manage post contingent voltage oscillation	1390 (115.83)	System Strength
V_ARARATWF_FLT_0	Limit Ararat Wind Farm upper limit to 0 MW to manage post contingent voltage oscillation	1362 (113.5)	System Strength
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	1325 (110.41)	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	1156 (96.33)	Thermal
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.	1146 (95.5)	Transient 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>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	3,231,553	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 [Note: swamped with 96M or 9UJ or 9UH is O/S]	2,388,270	Thermal
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1,455,337	Thermal
V_ARARATWF_FLT_0	Limit Ararat Wind Farm upper limit to 0 MW to manage post contingent voltage oscillation	1,400,683	System Strength
V_WEMENSF_FLT_45	Limit Wemen Solar Farm upper limit to 45 MW to manage post contingent voltage oscillation	1,060,731	System Strength
V_BANNERTSF_FLT_45	Limit Bannerton Solar Farm upper limit to 45 MW to manage post contingent voltage oscillation	1,047,520	System Strength
V_KIAMSF_FLT_50	Limit Kiamal solar farm upper limit to 50 MW to manage post contingent voltage oscillation	1,009,605	System Strength
V_MURRAWRWF_FLT_100	Limit Murra Warra Wind Farm 1+2 upper limit to 100 MW to manage system stability on the next contingency due to voltage oscillation	828,488	System Strength
N>>YSTX_TX_051	Out= One Yass 330/132kV TX, avoid O/L of other Yass 132/330kV TX on trip of Wagga to Lower Tumut (051) line, Feedback	709,385	Thermal
V_GANWRSF_FLT_30	Limit Gannawarra solar farm upper limit to 30 MW to manage post contingent voltage oscillation	682,030	System Strength

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 reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	17 (1.41)	Voltage Stability
N_FINLYSF_FLT_45	Limit Finley solar farm upper limit to 45 MW to manage post contingent voltage oscillation	9 (0.75)	System Strength
Q_STR_7C8C_KBWF	Limit Kaban Wind Farm output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	9 (0.75)	System Strength
NSA_Q_BARCALDN	Network Support Agreement for Barcaldine GT to meet local islanded demand for the planned outage of 7153 T71 Clermont to H15 Lilyvale or 7154 T72 Barcaldine to T71 Clermont 132kV line	7 (0.58)	Network Support
N_WSTWYSF1_0INV	West Wyalong Solar Farm inverter limit of zero. Constraint to violate if West Wyalong Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	7 (0.58)	System Strength
S_DLBAT-L_ISL	Out= Yorke Peninsula 132kV network islanded (i.e. island formed between Hummocks-Androssan West- Dalrymple 132kV network), Dalrymple Battery (Load Mode) islanded	6 (0.5)	Islanding - Unit
N_FINLYSF1_0INV	Finley Solar Farm inverter limit of zero. Constraint to violate if Finley Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	6 (0.5)	System Strength
N_METZSF_0INV	Metz Solar Farm inverter limit of zero. Constraint to violate if Metz Solar Farm inverter availability greater than zero. Swamp out otherwise. DS only	5 (0.41)	System Strength
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW	4 (0.33)	FCAS
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event, Basslink unable to transfer FCAS	4 (0.33)	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 equation violated for 17 non-consecutive DIs on 11/10/2023 0805 hrs to 19/10/2023 2145 hrs with a max violation degree of 50.1 MW occurring on 11/10/2023 1415 hrs. Constraint equation violated due to competing requirements with the import limits on DirectLink set by N_X_MBTE_3B.
N_FINLYSF_FLT_45	Constraint equation violated for 9 non-consecutive DIs on 12/10/2023 0950 hrs to 13/10/2023 0700 hrs with a max violation degree of 73.56 MW occurring on 12/10/2023 1430 hrs. Constraint equation violated due to Finley Solar Farm limited by its ramp down rate.
Q_STR_7C8C_KBWF	Constraint equation violated for 8 consecutive DIs on 18/10/2023 from 1005 hrs to 1040 hrs and 1 DI on 19/10/2023 0805 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Kanban Wind Farm exceeding its MVar limit.
NSA_Q_BARCALDN	Constraint equation violated for 7 non-consecutive DIs on 4/10/2023 0720 hrs to 4/10/2023 1855 hrs with a max violation degree of 21.31 MW occurring on 4/10/2023 0730 hrs. Constraint equation violated due to Barcaldine GT non-conforming to the Network Service Agreement requirement to meet local islanded demand.
N_WSTWYSF1_0INV	Constraint equation violated for 7 non-consecutive DIs on 9/10/2023 1335 hrs to 10/10/2023 0915 hrs with a violation degree of 0.001 MW. Constraint equation violated due to West Wyalong Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
S_DLBAT-L_ISL	Constraint equation violated for 6 consecutive DIs on 24/10/2023 from 1135 hrs to 1200 hrs with a max violation degree of 0.18 MW occurring on 24/10/2023 1150 hrs. Constraint equation violated due to small non-zero SCADA values when Dalrymple Battery was not generating.
N_FINLYSF1_0INV	Constraint equation violated for 6 non-consecutive DIs on 6/10/2023 0605 hrs to 17/10/2023 1805 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Finley Solar Farm exceeding its inverter limit.
N_METZSF_0INV	Constraint equation violated for 5 consecutive DIs on 24/10/2023 from 0505 hrs to 0525 hrs with a violation degree of 0.001 MW. Constraint equation violated due to Metz Solar Farm exceeding its inverter limit.
F_T+RREG_0050	Constraint equation violated for 4 non-consecutive DIs on 1/10/2023 0135 hrs to 25/10/2023 0800 hrs with a max violation degree of 21.95 MW occurring on 5/10/2023 0855 hrs. Constraint equation violated due to Tasmania raise regulation availability being less than the requirement.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 4 non-consecutive DIs on 05/10/2023 1830 hrs to 15/10/2023 2240 hrs with a max violation degree of 12.3 MW occurring on 6/10/2023 0445 hrs. Constraint equation violated due to the Tasmania raise 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-LS_SVC	N-Q-MNSP1 Export	Out= Lismore SVC O/S or reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	3294 (274.5)	-39.77 (-29.0)
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	1271 (105.92)	160.87 (192.98)
VT_ZERO	T-V-MNSP1 Import	Vic to Tas on Basslink upper limit of 0 MW	1074 (89.5)	0.0 (0.0)
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	1034 (86.17)	-348.88 (-462.0)
N>>964_86_85_S	NSW1-QLD1 Import	Out= Taree to Port Macquarie (964) 132kV line, avoid O/L Armidale to Tamworth (86) on trip of Uralla to Tamworth (85) line, Feedback	878 (73.17)	-562.74 (-1065.93)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	777 (64.75)	28.0 (462.0)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	750 (62.5)	-427.3 (-461.69)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	675 (56.25)	1187.31 (1474.77)
N_MBTE1_B	N-Q-MNSP1 Import	Out= one Directlink cable, Qld to NSW limit	647 (53.92)	-107.19 (-152.3)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	633 (52.75)	-93.48 (169.52)

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_542A136B	30/09/2023 12:30 to 01/10/2023 18:05	CA_BRIS_542A136B was created to manage post contingent overloads on Lismore – Koolkhan 967 132 kV line during a prior outage of Tenterfield – Lismore 96 L 132 kV line.
CA_SYDS_544A2F7F	24/10/2023 21:20 to 25/10/2023 06:45	CA_SYDS_544A2F7F was created to manage the overload of 998 Cowra – Forbes 132 kV line for trip of large NSW/QLD units, or 4 line or 5 line with an existing outage of 3H Crookwell to Gullen Range 300 kV line.

2.5.1 Further Investigation

CA_BRIS_542A136B: Please refer to September Constraint report for further investigation.

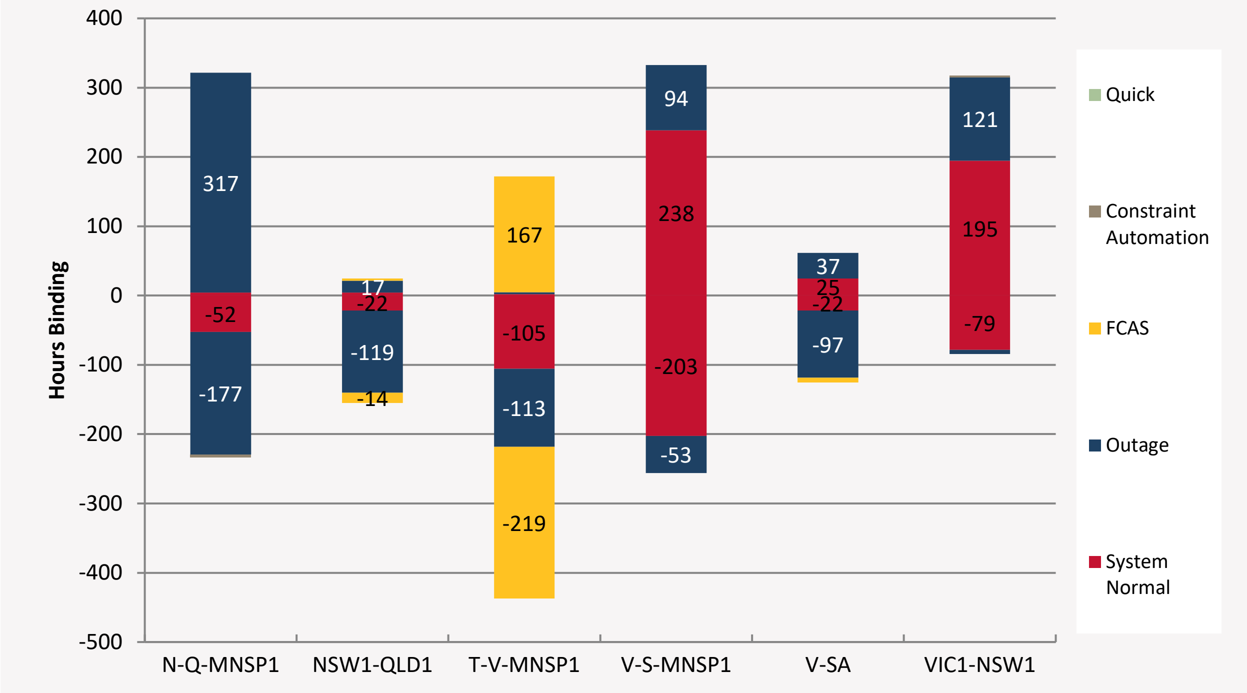
CA_SYDS_544A2F7F: Constraint was invoked and binding. Constraint was revoked after new constraint N-CRGR_3H was built to manage ongoing and future violation issues.

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.

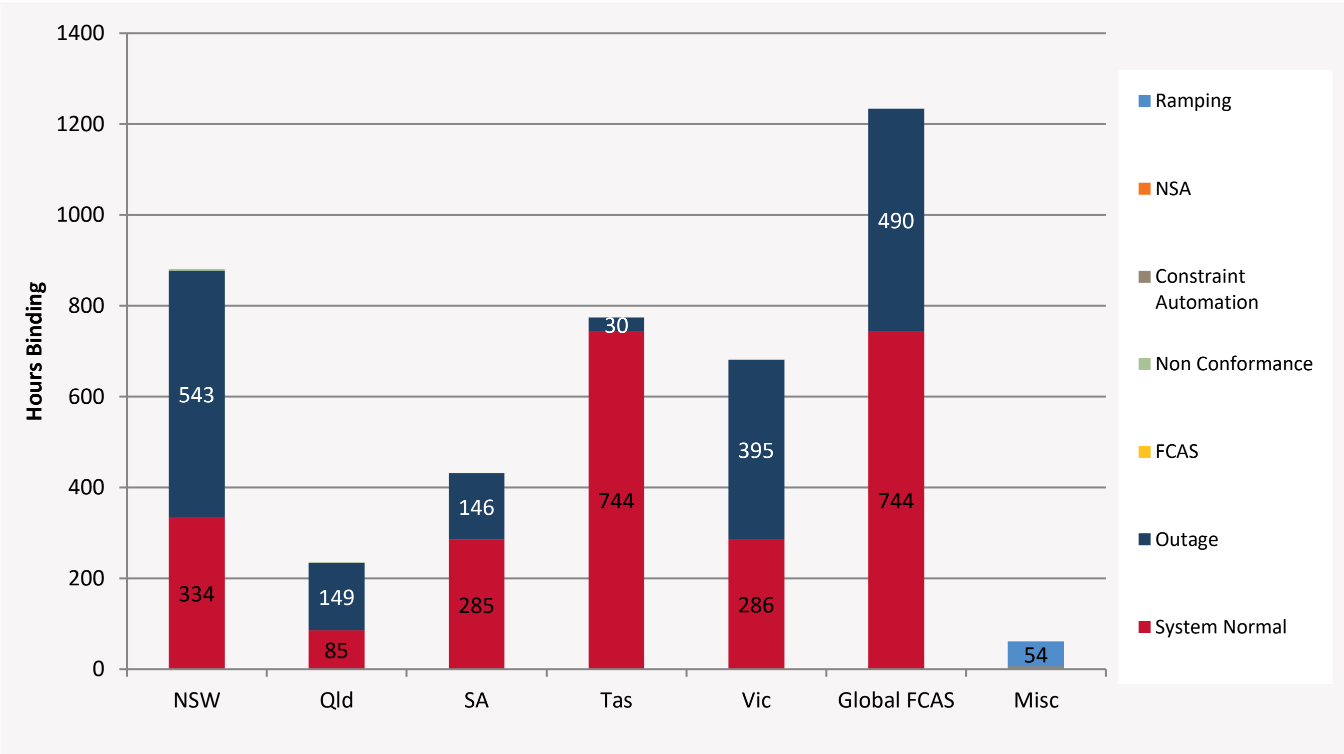
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

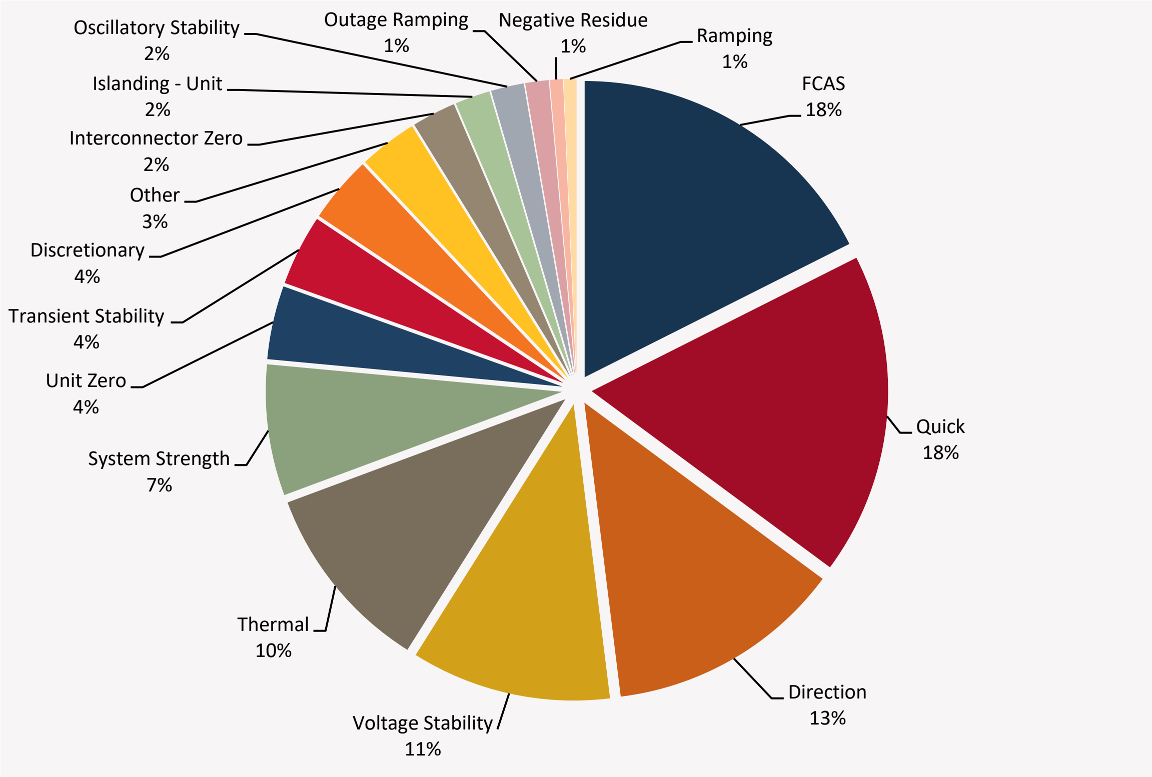
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

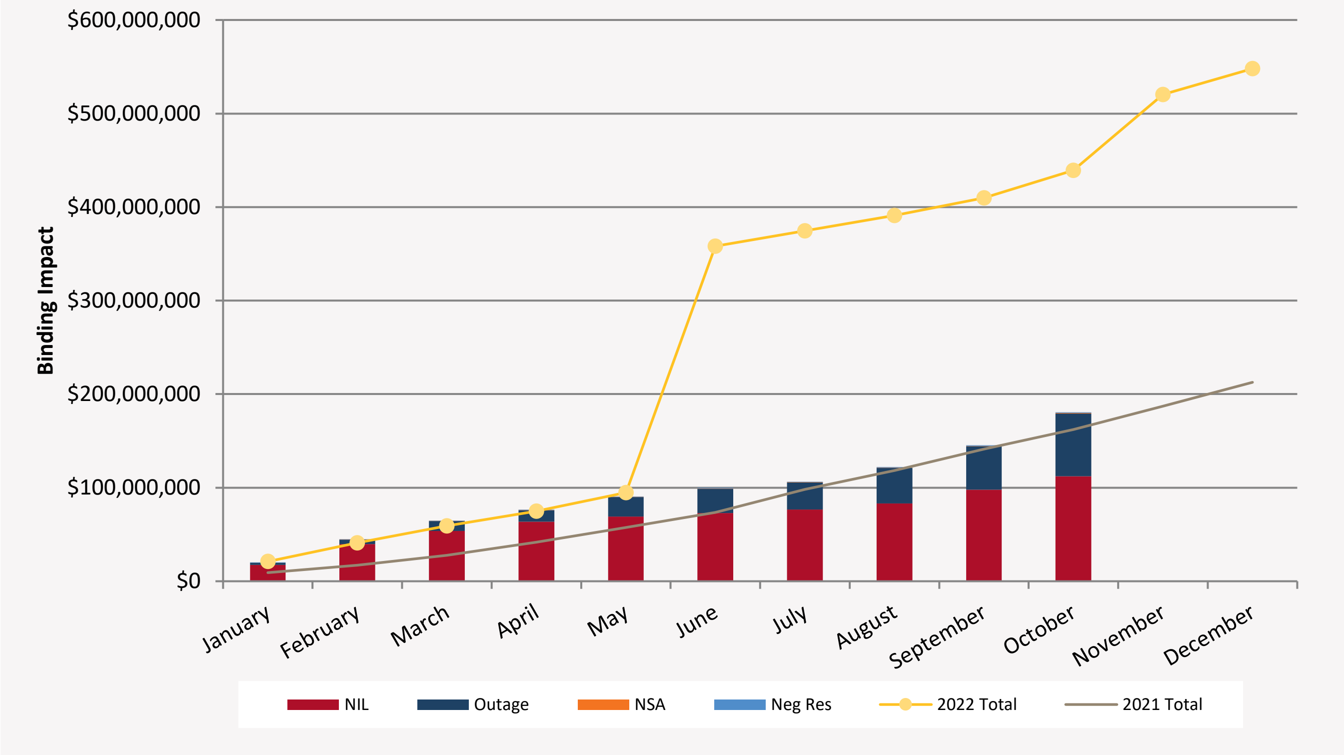
Figure 3 Binding by limit type



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
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	154	313,404% (96.38)	2,155% (16.96)
Q_STR_7C2K_KBWF_12	No limit to Kaban if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7,Kar >=2, NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton syncon ON(Haughton syncon OFF 50% daytime,100% at night) ,1% if Kar < 2 or Kareeya >=2, NQLD>250&Ross_FN>100, Zero otherwise.	14	4,963% (74.5)	2,482% (37.25)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	19	3,250% (32.5)	707% (18.4)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	18	2,680% (33.)	706% (17.4)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V^SML_KGRC_4	Out = Kerang to Wemen or Red Cliffs to Wemen 220kV line sections, or full Kerang to Wemen to Red Cliffs 220kV line, avoid voltage collapse for loss of Horsham to Ararat 220kV line	6	2,328% (63.9)	796% (33.19)
CA_BRIS_542A136B_1	Constraint Automation, O/L 967:L967:I:132@LISMORE@NSW for CTG LNPD on trip of COFFS-LISMORE 89 330KV LINE. Generated by STNET[NORCR1] Host BNEREGEEMP5(EMPBRI)	10	1,305% (213.49)	464% (104.43)
S^^V_SETB_1	Out= one South East to Tailem Bend 275kV line, voltage collapse equation Tailem Bend-Keith #2 132kV Line <=135 MW on trip of other Tailem Bend-South East 275kV line, Feedback (Note: with both SE series caps I/S or O/S)	39	552% (37.51)	187% (23.32)
T>T_HA_TX	Out = Hadspen 220/110 kV txfmr, avoid O/L Palmerston 220/110 kV txfmr (flow from 220 kV to 110 kV) on trip of remaining Hadspen 220/110 kV txfmr, feedback	4	508% (78.78)	353% (60.59)
N^N-LS_SVC	Out= Lismore SVC O/S or reactive power control mode,avoid Voltage collapse on TL 87/89 trip;[Swamped for 3 DLK cables are O/S Or when ECS is enabled with DLK is exporting to QLD,sets DLK to -29 MW for -29< DLK FLOW<0, checks ETS status & unswamps if O/S)	194	209% (62.42)	68.36% (23.12)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V:T_HAGT_BL_1: Investigated and no improvement can be made to the constraint equation at this stage.

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

N^N-X_LS_SVC+96R: Investigated and no improvement can be made to the constraint equation at this stage.

V:T_HAPM_BL_1: Investigated and no improvement can be made to the constraint equation at this stage.

N>>NIL_964_84_S: Investigated and no improvement can be made to the constraint equation at this stage.

N::Q_ARSR_1: Investigated and no improvement can be made to the constraint equation at this stage.

Q_STR_7C2K_KBWF_12: Investigated and no improvement can be made to the constraint equation at this stage.

N>GITN-96R_967_89: Investigated and no improvement can be made to the constraint equation at this stage.

N^N-X_LS_SVC+96R: Investigated and no improvement can be made to the constraint equation at this stage.

S^^V_SETB_1: Investigated and no improvement can be made to the constraint equation at this stage.

N>>NIL_964_84_S: Investigated and constraint equation was updated on 30/10 to improve PD performance.

N>NIL_969: 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_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^N-LS_SVC: Investigated and constraint equation was updated on 27/08 to improve PD performance.

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 October 2023.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Dr Enelx V240	3 October 2023	Victoria	New Generator - WDR
Tallawara B 320 MW OCGT	10 October 2023	NSW	New Generator
R4 Millmerran – H14 Middle Ridge No. 9907 330 kV Line.	11 October 2023	QLD	Line Decommissioned
R4 Millmerran – R14 Tummaville No. 9914 330 kV Line.	11 October 2023	QLD	Line Commissioned cutting decommissioned line into Tummaville.
R14 Tummaville – H14 Middle Ridge No. 9907 330 kV Line.	11 October 2023	QLD	Line Commissioned cutting decommissioned line into Tummaville.
Western Downs – Banana Bridge No. 8990 275 kV Line.	16 October 2023	QLD	Line Commissioned

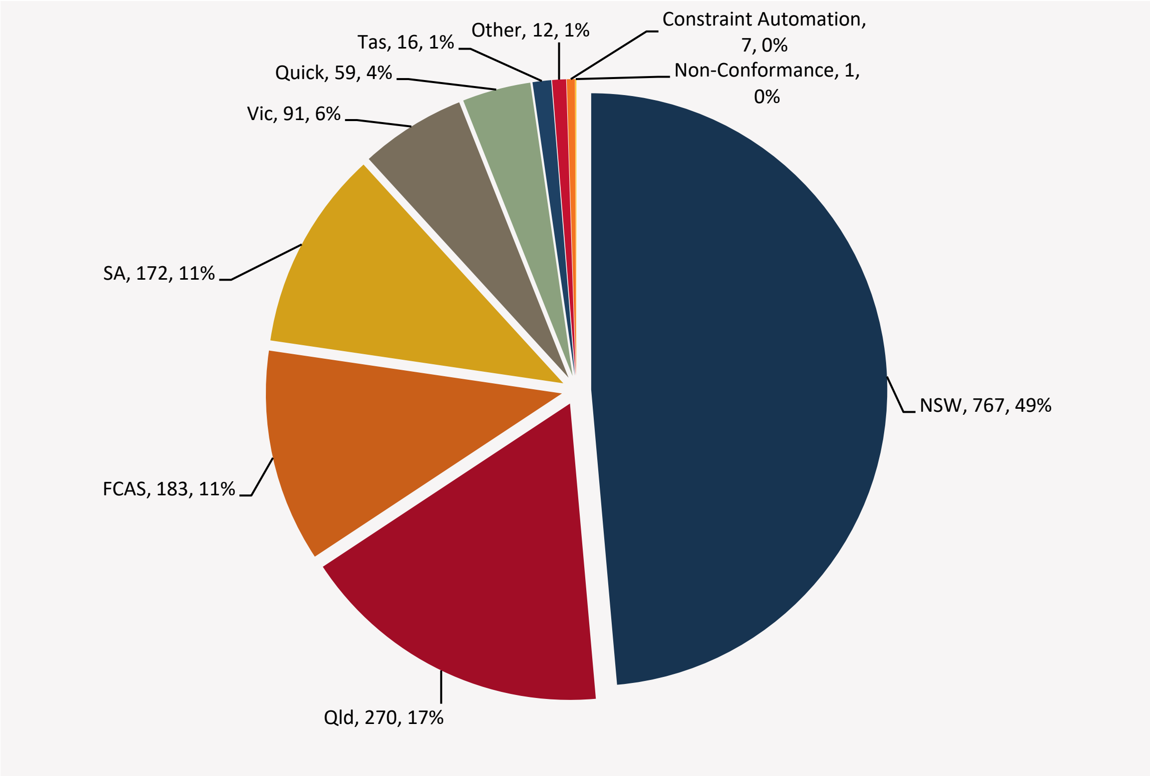
3.1 Constraint Equation Changes

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