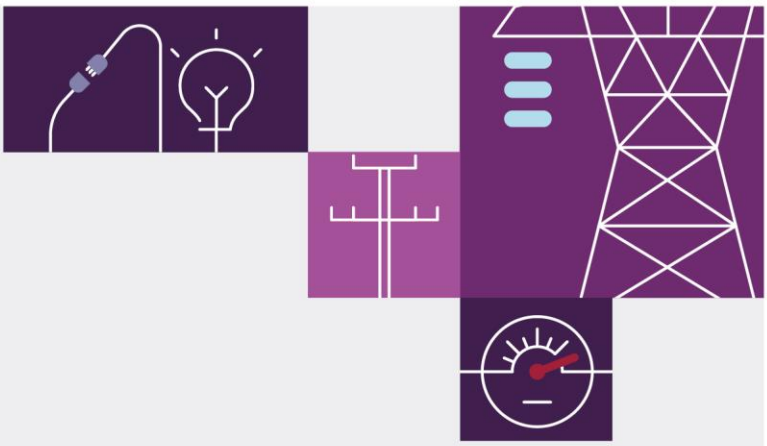
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

October 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 October 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	5279 (439.91)	Unit Zero
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	4139 (344.91)	Voltage Stability
Q_STR_7C0K_HASF	No limit to Haughton Solar Farm if Stan>=2+Stan+Cal>=3+Glad>=2+ (Stan+Cal+Glad) >=7,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON, Zero otherwise.	2828 (235.66)	System Strength
T_WIND_NTH_100	100 MW upper limit on TAS North Wind Generation	2486 (207.16)	Transient Stability
T>T_X_NTH_STH_B	Out = Credible risk of, or actual, Tas Nth-Sth separation. Limit southern generators to >= southern load - 15 MW	1920 (160.0)	Thermal
Q_KEP-HYB_25MW	Kennedy Energy Park upper limit of 25MW	1889 (157.41)	Discretionary
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1831 (152.58)	Thermal
N>NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1692 (141.0)	Thermal
Q>>BCST_BCST_CLWU	Out = 848 or 849 H10 Bouldercombe to H29 Stanwell 275 kV line, avoid O/L the remaining Stanwell to Bouldercombe 848 or 849 on trip of Calvale to Wurdong (871) line, Feedback	1638 (136.5)	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	1499 (124.91)	Voltage 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	2,302,518	Thermal
N>NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1,919,125	Thermal
T_WIND_NTH_100	100 MW upper limit on TAS North Wind Generation	1,622,601	Transient Stability
N_TARALGAWF_ZERO	Taralga WF upper limit of 0 MW	1,508,017	Unit Zero
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria	1,203,968	Voltage Stability
N>NIL_94K_1	Out= Nil, avoid O/L Suntop Tee to Wellington (94K/1) on trip of Nil, Feedback	1,056,855	Thermal
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	936,337	Thermal
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	862,745	Thermal
Q_KEP-HYB_25MW	Kennedy Energy Park upper limit of 25MW	749,495	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	515,882	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_T+STH_MG_R6	Raise 6 sec requirement for a South Tasmania Generation Event	54 (4.5)	FCAS
F_T+NTH_MG_R6	Raise 6 sec requirement for a North Tasmania Generation Event, Basslink unable to transfer FCAS	15 (1.25)	FCAS
F_T+NTH_ML_L6	Lower 6 sec requirement for a North Tasmania Load Event, Basslink unable to transfer FCAS	12 (1.0)	FCAS
SVML^NIL_MH-CAP_ON	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.)	12 (1.0)	Voltage Stability
F_T+STH_NYR_ML_L6	Lower 6 sec requirement for South Tasmania for loss of Nyrstar load	11 (0.91)	FCAS
V_COHUNASF_0INV	Constraint to violate if Cohuna Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	9 (0.75)	System Strength
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	7 (0.58)	FCAS
N_GOONSF1_0INV	Constraint to violate if Goonumbla Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	7 (0.58)	System Strength
F_S++HYSE_L6_1	Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 6 sec Requirement for risk of islanding, segment1	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

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_T+STH_MG_R6	Constraint Equation violated for 54 non-consecutive Dis on 14/10/2022 from 1010 hrs to 1915 hrs with a max violation of 81.06 MW occurring at 1835 hrs. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
F_T+NTH_MG_R6	Constraint Equation violated for 15 non-consecutive Dis on 14/10/2022 from 1010 hrs to 1510 hrs with a max violation of 44.55 MW occurring at 1105 hrs. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
F_T+NTH_ML_L6	Constraint Equation violated for 12 non-consecutive Dis on 14/10/2022 from 1010 hrs to 1605 hrs with a max violation of 36.16 MW occurring at 1010 hrs. Constraint equation violated due to the Tasmania lower 6 second availability being higher than the requirement.
SVML^NIL_MH-CAP_ON	The constraint equation violated for 12 consecutive DIs on 24/10/2022 from 0540 hrs to 0630 hrs with a max violation of 3.73 MW at 0615 hrs. Constraint equation violated due to competing requirements with export limits on the Murraylink interconnector which were set by I_CTRL_ISSUE_ML.
F_T+STH_NYR_ML_L6	The constraint equation violated for 11 non-consecutive Dis from 22/10/2022 1820hrs to 30/10/2022 2325 hrs with a max violation of 20.2 MW occurring on 26/10/2022 1150hrs. Constraint violated due to South Tasmania lower 6 second availability being less than the requirement.
V_COHUNASF_0INV	The constraint equation violated for 9 consecutive Dis on 27/10/2022 from 0605 hrs to 0705 hrs with a max violation degree of 0.001 hrs. Constraint equation violation occurred due to Cohuna Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
F_T_AUFLS2_R6	The constraint equation violated for 7 non-consecutive Dis from 2/10/2022 1315 hrs to 19/10/2022 0650 hrs with a max violation of 4.75 MW occurring at 11/10/2022. The constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
N_GOONSF1_0INV	The constraint equation violated for 7 consecutive Dis on 15/10/2022 from 0700 hrs to 0730 hrs with a violation degree of 0.001 MW. Constraint violated due to Goonumbla Solar Farm exceeding its inverter limit.
F_S++HYSE_L6_1	The constraint equation violated for 6 consecutive Dis on 19/10/2022 from 1000 hrs to 1025 hrs with a max violation of 70.51 MW occurring at 1020 hrs. Constraint violated due to SA Lower 6 second availability being less than the requirement.
F_T+NIL_MG_RECL_R6	The constraint equation violated for 6 non-consecutive Dis from 19/10/2022 0650 hrs to 31/10/2022 2045 hrs with a max violation of 18.68 MW occurring at 29/10/2022 0535 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 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	4139 (344.92)	-44.38 (96.57)
Q>>BCST_BCST_CLWU	NSW1-QLD1 Export	Out = 848 or 849 H10 Bouldercombe to H29 Stanwell 275 kV line, avoid O/L the remaining Stanwell to Bouldercombe 848 or 849 on trip of Calvale to Wurdong (871) line, Feedback	1634 (136.17)	-267.43 (700.0)
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	1204 (100.33)	106.94 (-145.29)
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	1176 (98.0)	328.76 (1158.04)
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	996 (83.0)	-288.81 (-478.0)
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	893 (74.42)	159.08 (180.32)
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	761 (63.42)	333.78 (1028.14)
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	738 (61.5)	-333.18 (-478.0)
S>>X_RBTU+RBTX_15	V-S-MNSP1 Import	Out= One Robertstown TX 275/132 kV + Robertstown-Tungkillo 275kV line O/S, avoid O/L of remaining Robertstown 275/132kV TX on trip of Robertstown-Para 275kV line, Feedback	652 (54.33)	-16.31 (-112.37)
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	625 (52.08)	-294.21 (-478.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
		a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS		

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_525A7773	13/10/2022 20:45 to 13/10/2022 20:55	Constraint CA_SYDS_525A7773 created to manage overloading of Robertstown 275/132 kV transformer 1 on loss of Robertstown – Para 275 kV line.
CA_SYDS_525A7AB7	13/10/2022 21:00 to 13/10/2022 21:40	CA_SYDS_525A7AB7 was created for the same reason as above. It was revoked after the Robertstown 275/132 kV transformer 1 rating was temporarily reduced from 160 MVA to 150 MVA.
CA_SYDS_525B969A	14/10/2022 17:15 to 19/10/2022 12:45	CA_SYDS_525A7AB7 was created to manage overloading of New Norfolk – Creek Road 110 kV line on trip of Chapel Street - New Norfolk 110 kV line

2.5.1 Further Investigation

CA_SYDS_525A7773: Auto constraint CA_SYDS_525A7773 (margin 20) was invoked from 20:40 to 20:55. This constraint did not bind. The auto constraint was revoked and S>>X_RBTU+RBTX_15 was created to manage the ongoing and future violations.

CA_SYDS_525A7AB7: A new auto constraint with a margin of 30 was built. This constraint CA_SYDS_525A7AB7 (margin 30) was invoked from 20:55 to 21:40. This constraint did not bind. -The auto constraint was revoked and S>>X_RBTU+RBTX_15 was created to manage the ongoing and future violations.

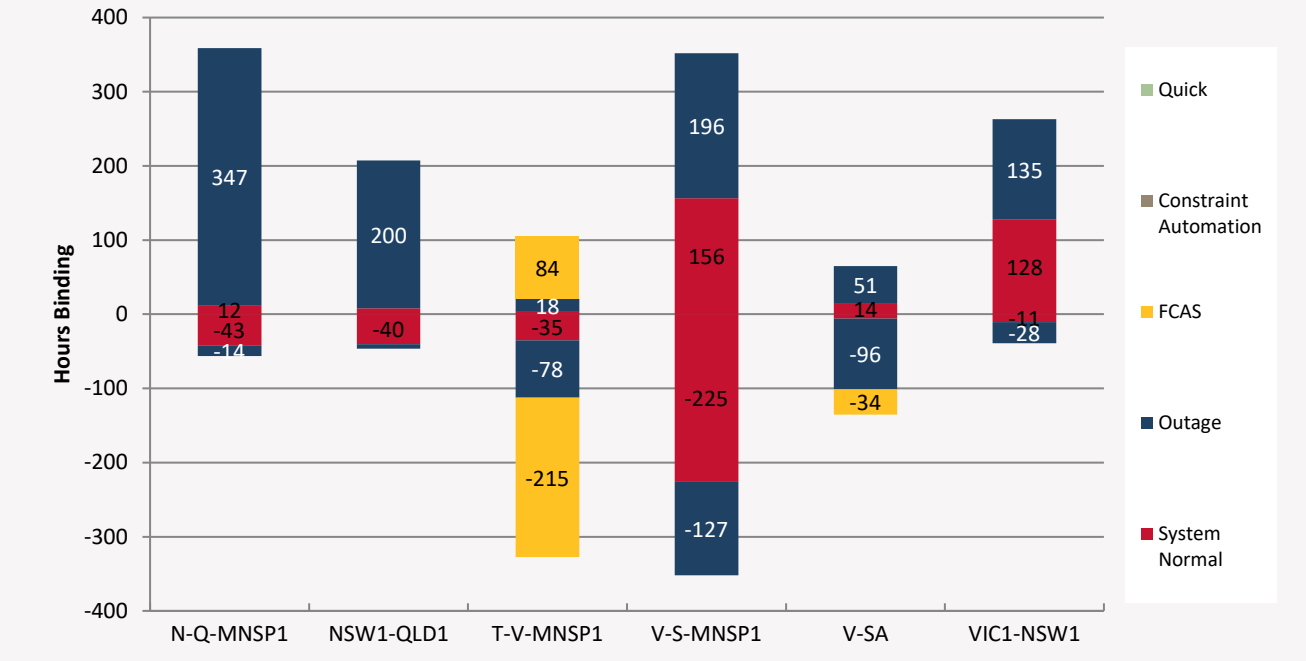
CA_SYDS_525B969A: Constraint Automation CA_SYDS_525B969A created and invoked from 1710 hrs. The auto constraint was revoked and T>T_X_LIPM_TWO_C was created to manage the ongoing and future violations.

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.

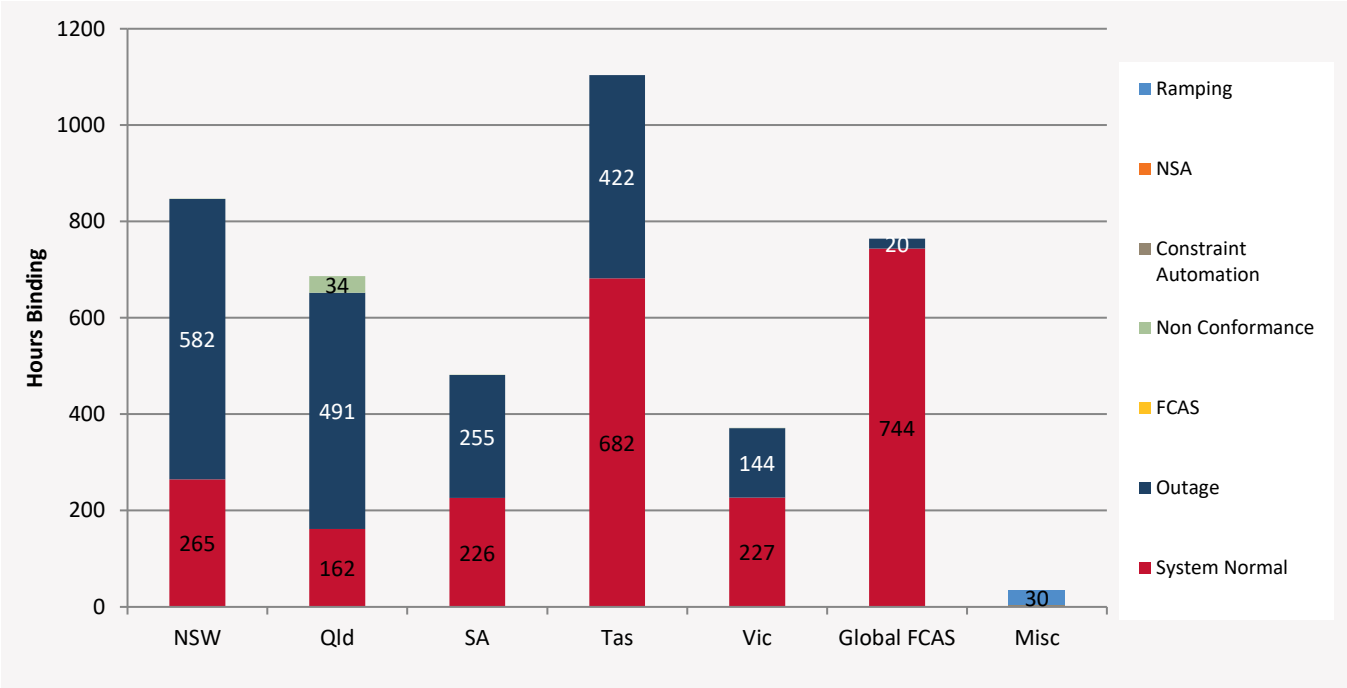
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

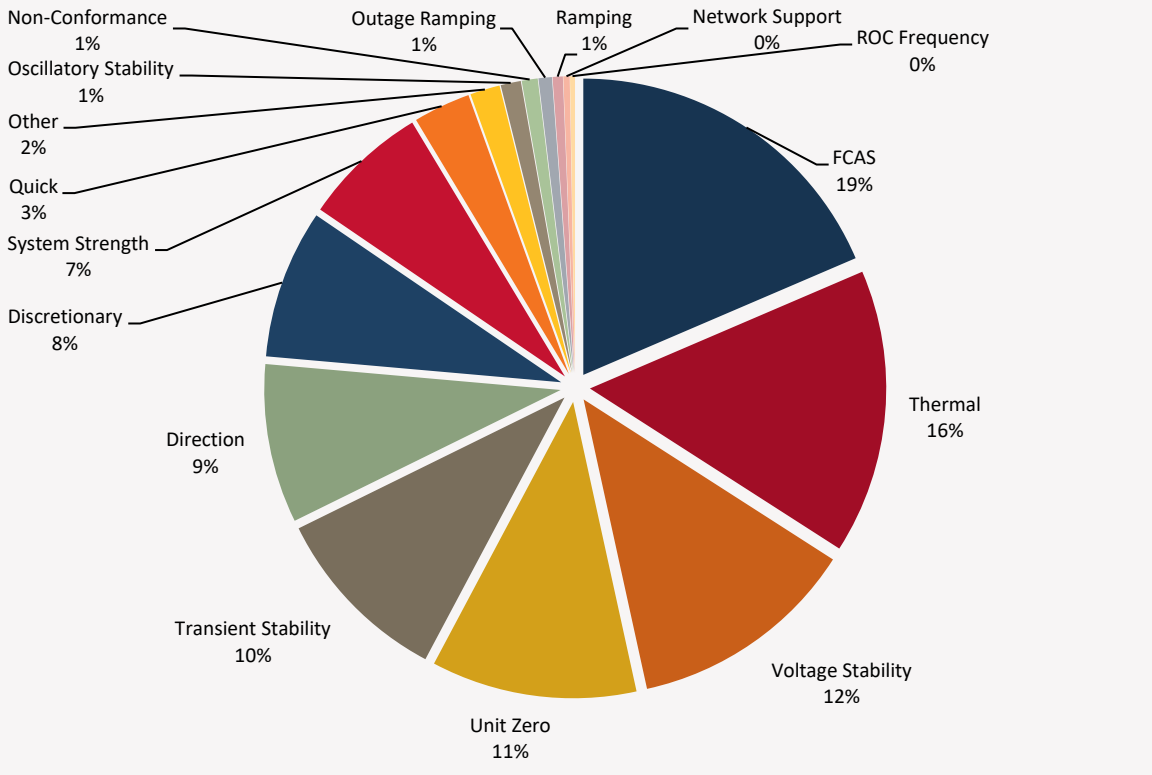
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

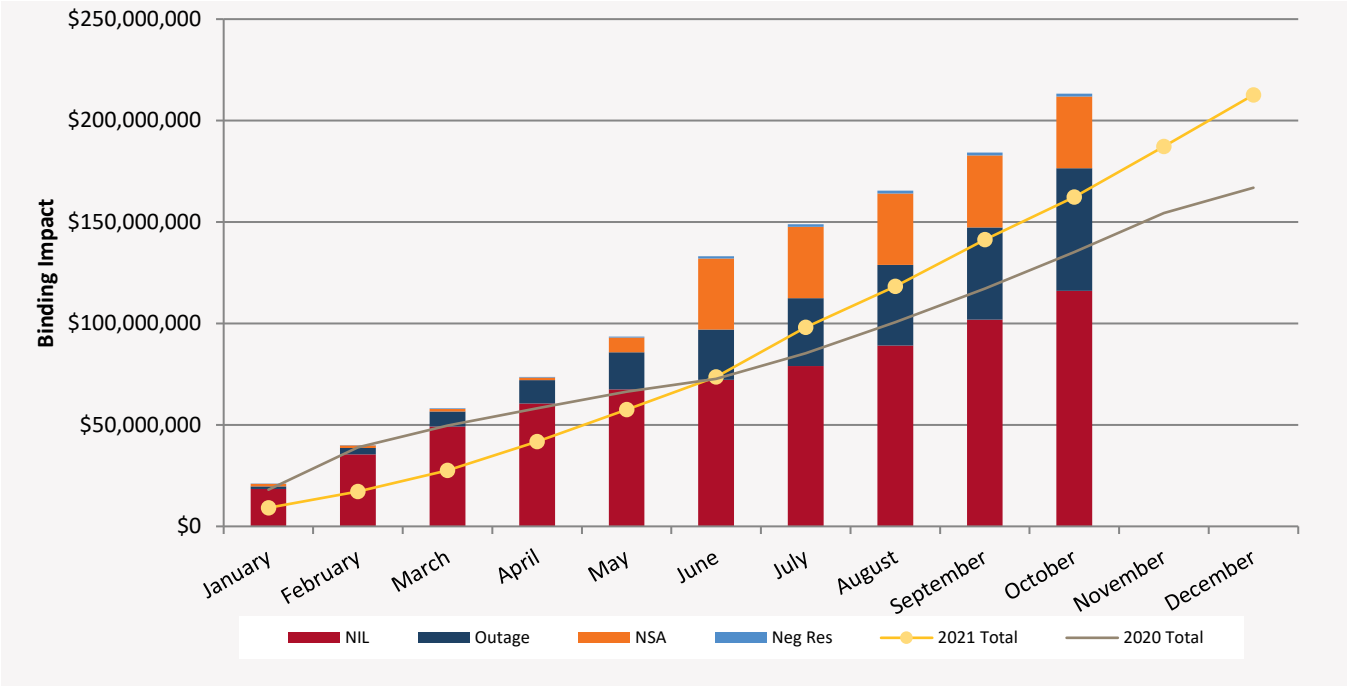
Figure 3 Binding by limit type



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	825	305,100% (136.18)	568% (27.53)
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.	46	5,025% (253.95)	234% (47.)
T_WIND_100	Limit output of TAS wind generation to less than 100 MW. Note, due to 144 MW rating of Non-Scheduled Woolnorth Wind Farm, directions may be required to reduce Woolnorth MW output if this constraint violates	169	2,643% (72.43)	359% (21.56)
T_WIND_NTH_100	100 MW upper limit on TAS North Wind Generation	419	1,697% (65.07)	198% (16.6)
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.	18	1,414% (269.89)	171% (85.32)

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	19	762% (92.39)	91.93% (30.1)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	123	564% (434.16)	22.88% (45.85)
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.	83	336% (225.71)	30.31% (64.58)
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.	64	145.29% (139.13)	22.35% (42.52)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

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

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

T_WIND_100: 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.

V^SML_BUDP_3: Investigated and no improvement can be made to the constraint equation at this stage.

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.

V::N_X_SMSC_O2: 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.

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 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Tumoulin 275kV Terminal Station	06/10/2022	QLD	Tumoulin cut in between Chalumbin and Woree 275 kV terminal stations has been commissioned
Moura Solar Farm	18 October 2022	QLD	New Generator

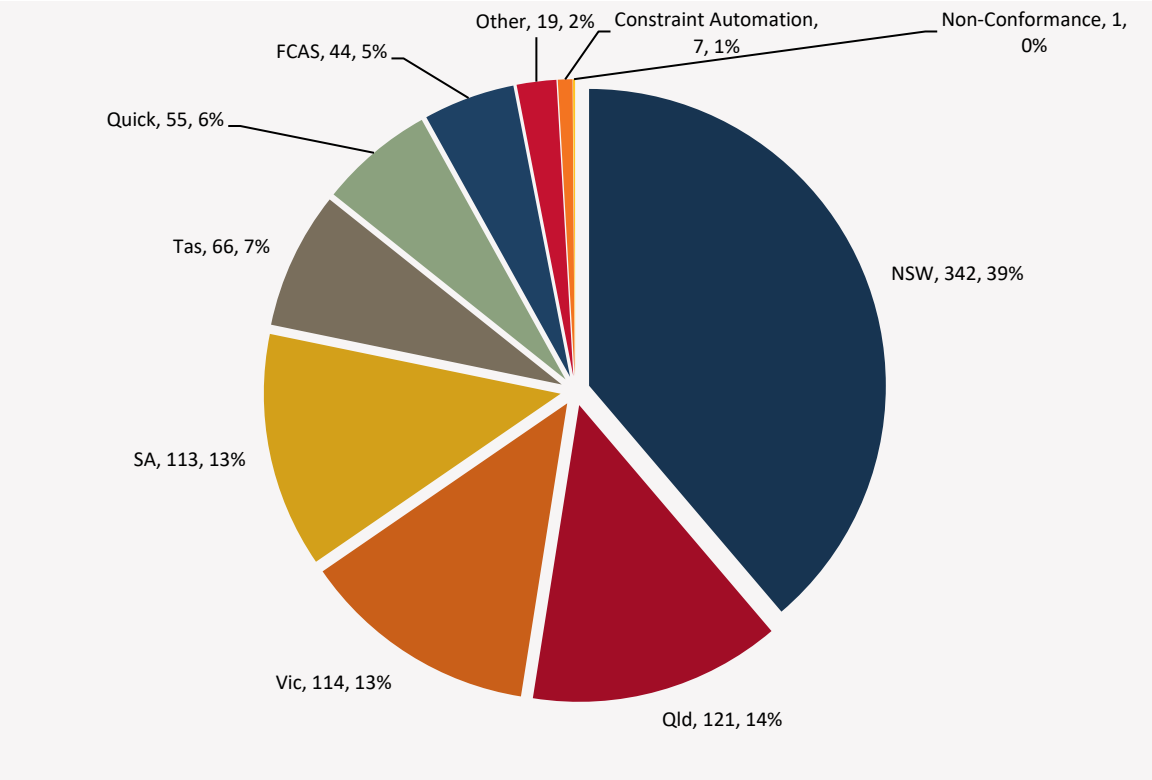
3.1 Constraint Equation Changes

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