AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

January 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 January 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^^Q_NIL_B1	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	2998 (249.83)	Voltage Stability
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	2833 (236.08)	Thermal
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2634 (219.5)	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	2171 (180.91)	Voltage Stability
N>N-NIL_LSDU	Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6), Feedback	1935 (161.25)	Thermal
V^^V_NIL_KGTS	Out= Nil, avoid voltage collapse for loss of either Crowlands - Bulgana - Horsham or Horsham - Murra Warra - Kiamal 220kV line	1794 (149.5)	Voltage Stability
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	1776 (148.0)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1501 (125.08)	Thermal
N^^Q_NIL_A	Out= Nil, avoid Voltage Collapse on loss of Liddell to Muswellbrook (83) line	1198 (99.83)	Voltage Stability
N>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	1031 (85.91)	Thermal

2.2 Top 10 binding impact constraint equations

Binding constraint equations affect electricity market pricing. The binding impact is used to distinguish the severity of different binding constraint equations.

The binding impact of a constraint is derived by summarising the marginal value for each dispatch interval (DI) from the marginal constraint cost (MCC) re-run[1] over the period considered. The marginal value is a mathematical term for the binding impact arising from relaxing the RHS of a binding constraint by one MW. As the market clears each DI, the binding impact is measured in $/MW/DI.

The binding impact in $/MW/DI is a relative comparison and a helpful way to analyse congestion issues. It can be converted to $/MWh by dividing the binding impact by 12 (as there are 12 DIs per hour). This value of congestion is still only a proxy (and always an upper bound) of the value per MW of congestion over the period calculated; any change to the limits (RHS) may cause other constraints to bind almost immediately after.

Table 2 Top 10 binding impact network constraint equations

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Limit Type
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	4,083,176	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	2,027,438	Thermal
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	2,019,177	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1,612,354	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	1,360,180	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	1,153,530	Voltage Stability
N>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	1,066,939	Thermal
V_NUMURKAH_ZERO	Numurkah Solar Farm upper limit of 0 MW	606,298	Unit Zero
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	418,479	FCAS
V>>V_NIL_18	Out= Nil, avoid O/L Ararat to Waubra 220kV line on trip of Kerang to Bendigo 220kV line, Feedback	347,886	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 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
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	24 (2.0)	Voltage Stability
F_T+NIL_MG_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	14 (1.16)	FCAS
N>>N-NIL_969	Out= Nil, avoid O/L Gunnedah to Tamworth (969) on trip of Nil, Feedback. Metering is used as specified in OM520	13 (1.08)	Thermal
N_COLMBSF_60_INV	Limit Coleambally Solar Farm upper limit to 0 MW if number of inverter available exceed 60. Dispatch only. swamped out if Inverters are within the limit.	9 (0.75)	System Strength
V>V_X_HWRO12_3	Out = Hazelwood to Rowville No. 1 and No. 2 220 kV lines, avoid O/L Yallourn to Rowville No. 5 220 kV line on trip of Yallourn to Rowville No. 6,7 or 8 220 kV lines, feedback, YWG1 on 220 kV, Radial mode	8 (0.66)	Thermal
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	8 (0.66)	FCAS
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	7 (0.58)	FCAS
F_T+NIL_MG_R60	Out = Nil, Raise 60 sec requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	6 (0.5)	FCAS
V>V_X_HWRO12_1	Out = Hazelwood to Rowville No. 1 and No. 2 220 kV lines, avoid O/L Yallourn to Rowville No. 6, 7 or 8 220 kV lines on trip of Yallourn to Rowville No. 5 220 kV line line, feedback, YWG1 on 220 kV, Radial mode	5 (0.41)	Thermal
V>V_X_HWRO12_5	Out = Hazelwood to Rowville No. 1 and No. 2 220 kV lines, avoid O/L Yallourn to Rowville No. 6,7 or 8 220 kV lines on trip of Yallourn to Rowville No. 6, 7 or 8 220 kV lines, feedback, YWG1 on 220 kV, Radial mode	5 (0.41)	Thermal

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
V^SML_BUDP_3	Constraint violated for 24 consecutive DIs on 11/01/2022 from 1905 hrs to 2100 hrs with a max violation of 60.31 MW occurring at 1905 hrs. Constraint equation violated due to competing requirements with the import limits on the Murraylink interconnector which were set by S>VMLMHNW2, SVML^NIL_MH-CAP_ON, SVML_FLT_130, and SVML_ROC_80. The line was not taken out of service until the violations cleared.
F_T+NIL_MG_R6	Constraint violated for 20 non-consecutive DIs with a max violation of 12.03 MW occurring on 28/01/2022 at 1420 hrs. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.
N>>N-NIL_969	Constraint violated for 13 non-consecutive DIs with a max violation of 16.97 MW occurring on 23/01/2022 at 0705 hrs. Constraint equation violated on 21/01/2022 and 22/01/2022 due to inflexible bidding from Gunnedah Solar Farm during generator testing. The constraint equation violated on 23/01/2022 due to Gunnedah Solar Farm non-conforming.
N_COLMBSF_60_INV	Constraint violated for 9 non-consecutive DIs with violation degree of 0.001 MW. Constraint equation violated due to Coleambally Solar Farm exceeding its inverter limit.
V>V_X_HWRO12_3	Constraint violated for 8 non-consecutive DIs with a max violation of 35.01 MW occurring on 10/01/2022 at 1125 hrs. Constraint equation violated due to a reduced rating on Yallourn to Rowville No. 5 220 kV line.
F_T_AUFLS2_R6	Constraint violated for 8 non-consecutive DIs with a max violation of 15.02 MW occurring on 16/01/2022 at 0410 hrs. Constraint equation violated due to the Tasmania raise 6 second availability being lower than the requirement.

Constraint Equation ID (System Normal Bold)	Description
F_T+NIL_WF_TG_R6	Constraint equation violated for 7 non-consecutive DIs with max violation of 16.13 MW occurring on 06/01/2022 at 1205 hrs. Constraint equation violated for the same reasons as above.
F_T+NIL_MG_R60	Constraint equation violated for 6 non-consecutive DIs with a max violation of 24.35 MW occurring on 03/01/2022 at 0320 hrs. Constraint equation violated due to the Tasmania raise 60 second availability being lower than the requirement.
V>V_X_HWRO12_1	Constraint equation violated for 5 non-consecutive DIs with a max violation of 200.68 MW occurring on 07/01/2022 at 1350 hrs. Constraint equation violated on 07/01/2022 due to in-service protection work on the Rowville – Yallourn 8 line resulting in a reduced LDSH rating for this line via SCADA, and on 10/01/2022 to 14/01/2022 due to decreased dynamic ratings on Yallourn to Rowville No. 6-8 220 kV lines.
V>V_X_HWRO12_5	Constraint equation violated for 5 non-consecutive DIs with a max violation of 194.25 MW occurring on 07/01/2022 at 1350 hrs. Constraint equation violated for the same reasons as above.

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^^Q_NIL_B1	NSW1-QLD1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	2998 (249.83)	314.12 (647.39)
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	2768 (230.67)	169.88 (199.23)
N^^Q_NIL_B1	N-Q-MNSP1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	2053 (171.08)	30.79 (74.61)
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	2013 (167.75)	127.67 (1154.12)
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	1431 (119.25)	155.93 (-98.49)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1257 (104.75)	-67.17 (454.01)
N^^Q_NIL_A	NSW1-QLD1 Export	Out= Nil, avoid Voltage Collapse on loss of Liddell to Muswellbrook (83) line	1198 (99.83)	466.16 (668.67)
N^^Q_NIL_A	N-Q-MNSP1 Export	Out= Nil, avoid Voltage Collapse on loss of Liddell to Muswellbrook (83) line	1166 (97.17)	23.29 (33.0)
F_MAIN++ML_L6_0400	T-V-MNSP1 Import	Out = Nil, Lower 6 sec requirement for a Mainland Load Event, ML = 400, Basslink able transfer FCAS	1089 (90.75)	-411.67 (-439.0)
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	1044 (87.0)	149.88 (-132.7)

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

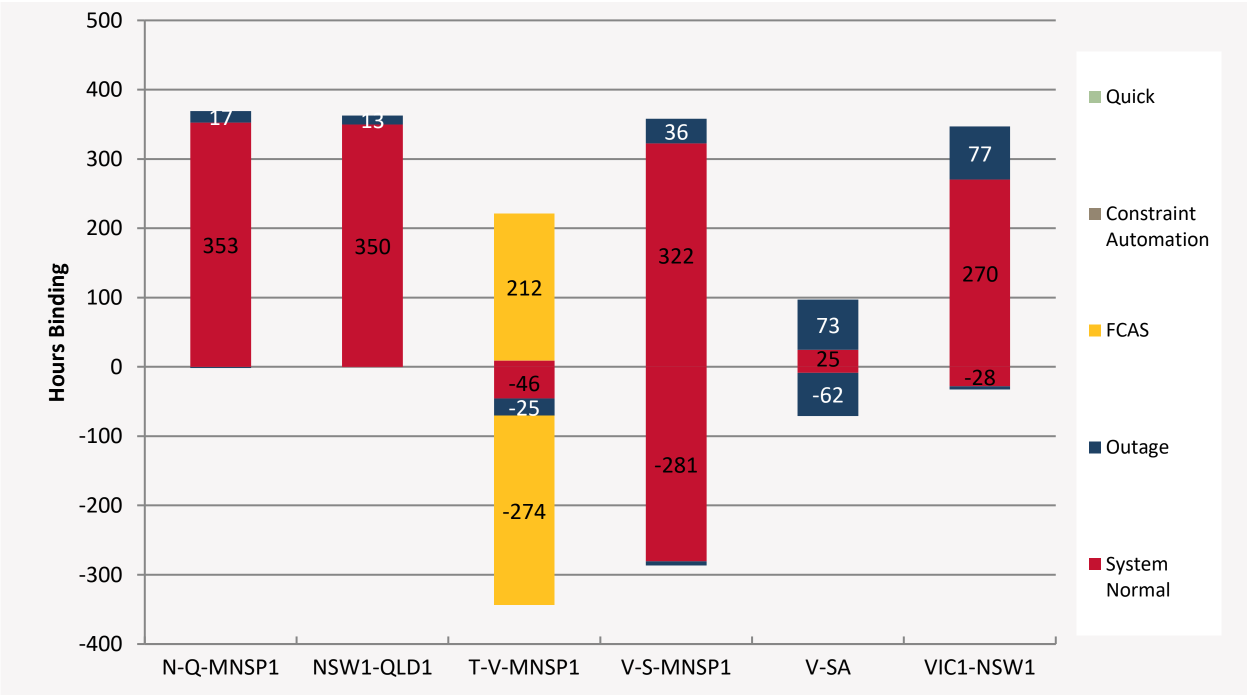
Non-real time constraint automation was not used.

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.

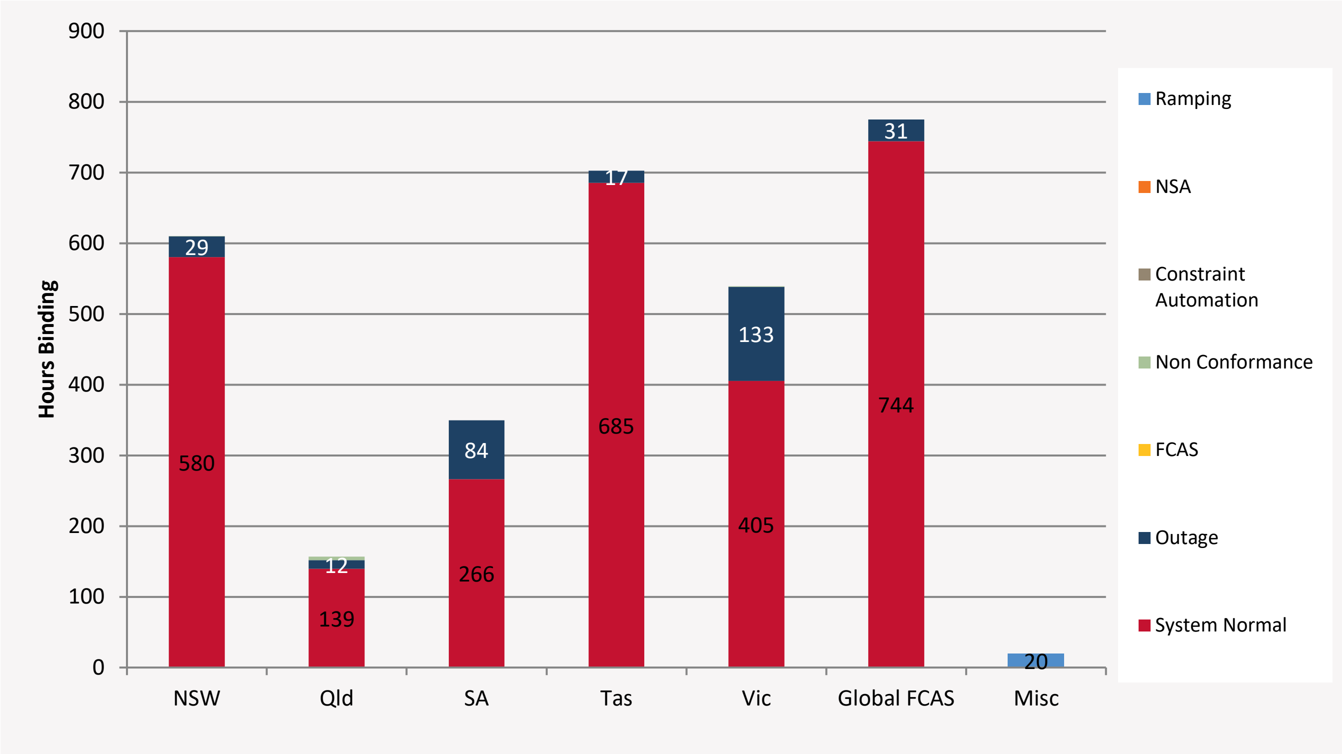
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

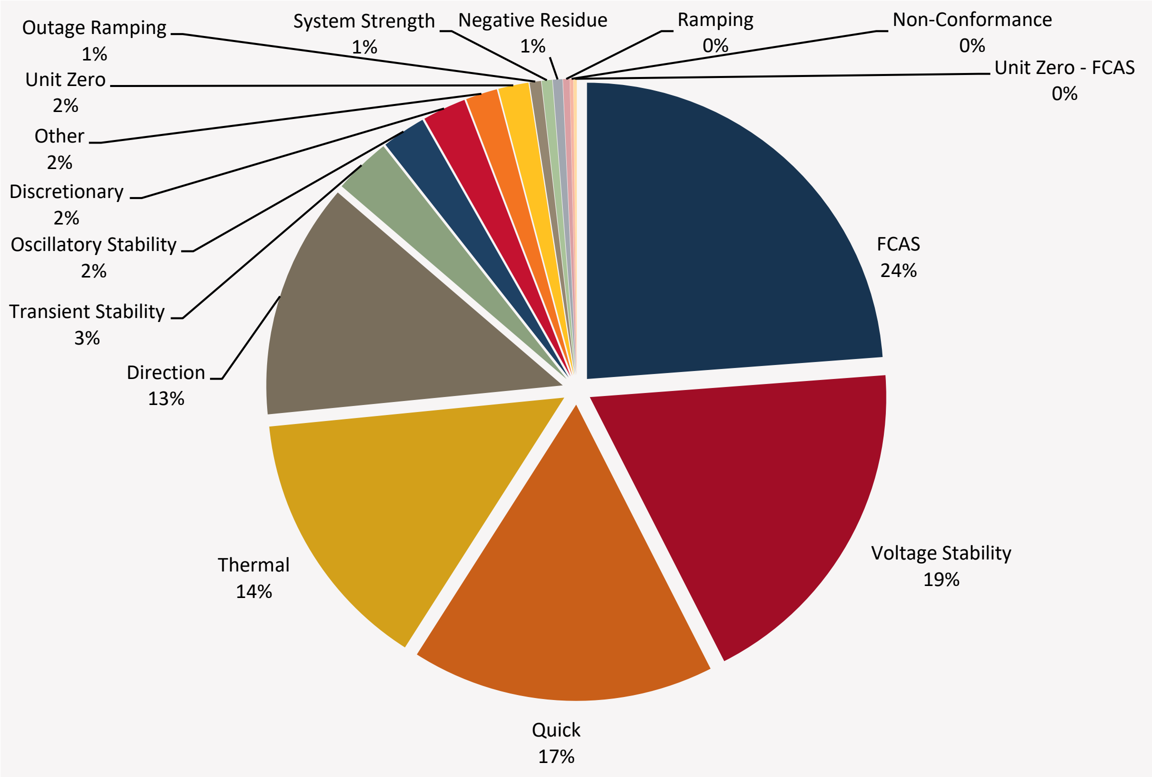
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

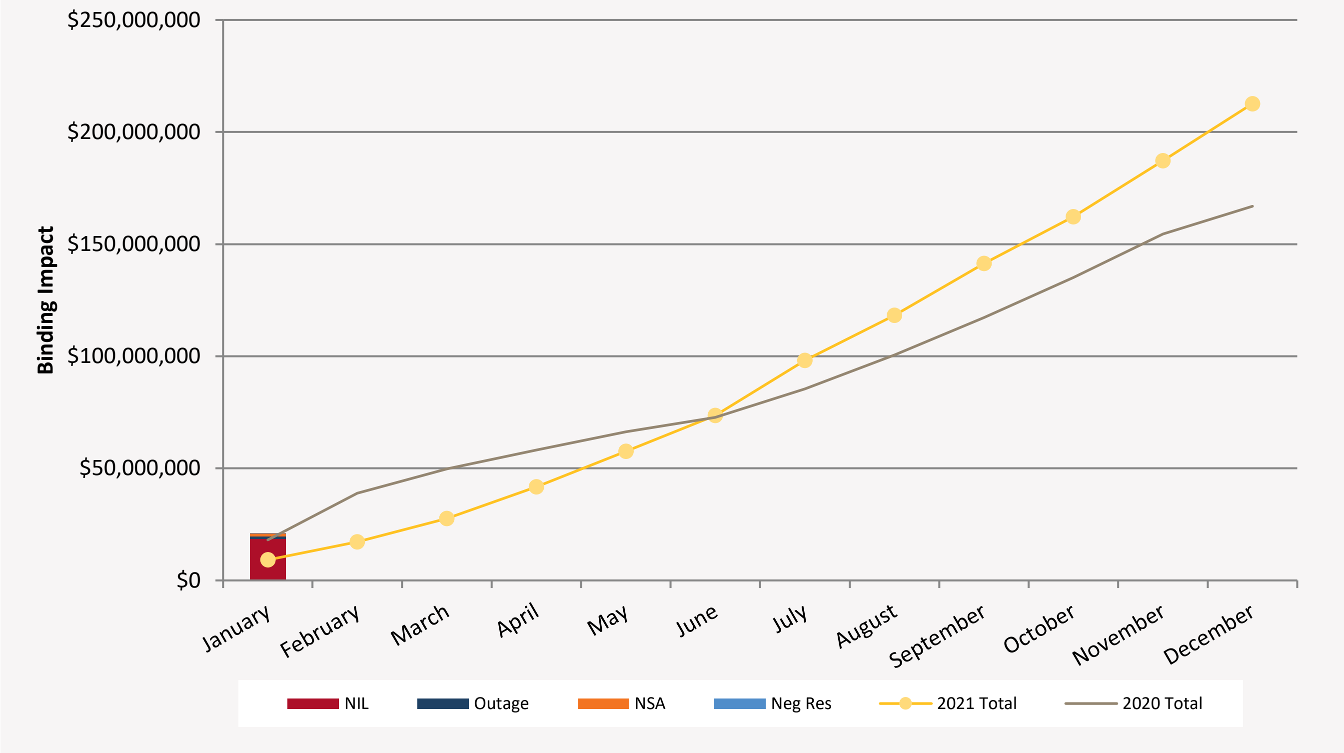
Figure 3 Binding by limit type



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
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	6	4,164% (247.11)	787% (83.31)
V_S_HEYWOOD_UFLS	Out= Nil, Limit Heywood flows when SA under frequency load shedding (UFLS) is insufficient (i.e. when UFLS blocks in SA <1000 MW) to manage for double-circuit loss of Heywood IC.Note: Constraint is swamped if UFLS blocks >= 1000 MW.	36	1,724% (9,452)	145.02% (811)
V::S_2SE+PAVC_MAXG	Out= Both South East SVC1 & SVC 2 + one Para SVC O/S (Note: with both Black Range series caps I/S); Vic to SA Transient Stability limit for loss of the largest generator in SA	63	453% (251.43)	69.11% (80.62)
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; TG formulation only	27	252% (99.25)	89.64% (36.07)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
N>N-NIL_LSDU	Out = Nil, avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6), Feedback	366	147.3% (69.52)	49.41% (27.43)
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	193	145.79% (281.35)	60.% (129.76)
NRM_NSW1_VIC1	Negative Residue Management constraint for NSW to VIC flow	3	100.% (9,276)	98.87% (9,236)
Q>NIL_MUTE_758	Out= Nil, ECS for managing 758 H4 Mudgeeraba to T174 Terranora 110kV line, Summer and Winter ECS ratings selected by SCADA status.	3	98.33% (99.95)	98.33% (99.95)
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.	78	86.44% (233.19)	19.89% (70.51)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

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

V::S_2SE+PAVC_MAXG: 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 27/08/2018 to improve PD performance.

N>N-NIL_LSDU: Investigated and the mismatch is due to modelling of DFS and SCADA value on Terranora load. DFS forecasting is being investigated to improve its performance. No improvements 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.

NRM_NSW1_VIC1: 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.

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 January 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Murray Bridge – Onkaparinga Pipeline Pumping Station 2 Solar Farm	11 January 2022	SA	New Generator
H5 Woolooga - T258 Widgee Creek No. 7471 132 kV line	13 January 2022	Qld	The H5 Woolooga - T258 Widgee Creek No. 7471 132 kV Line has been commissioned
St Leonards Schedule Load	25 January 2022	Tas	New Load

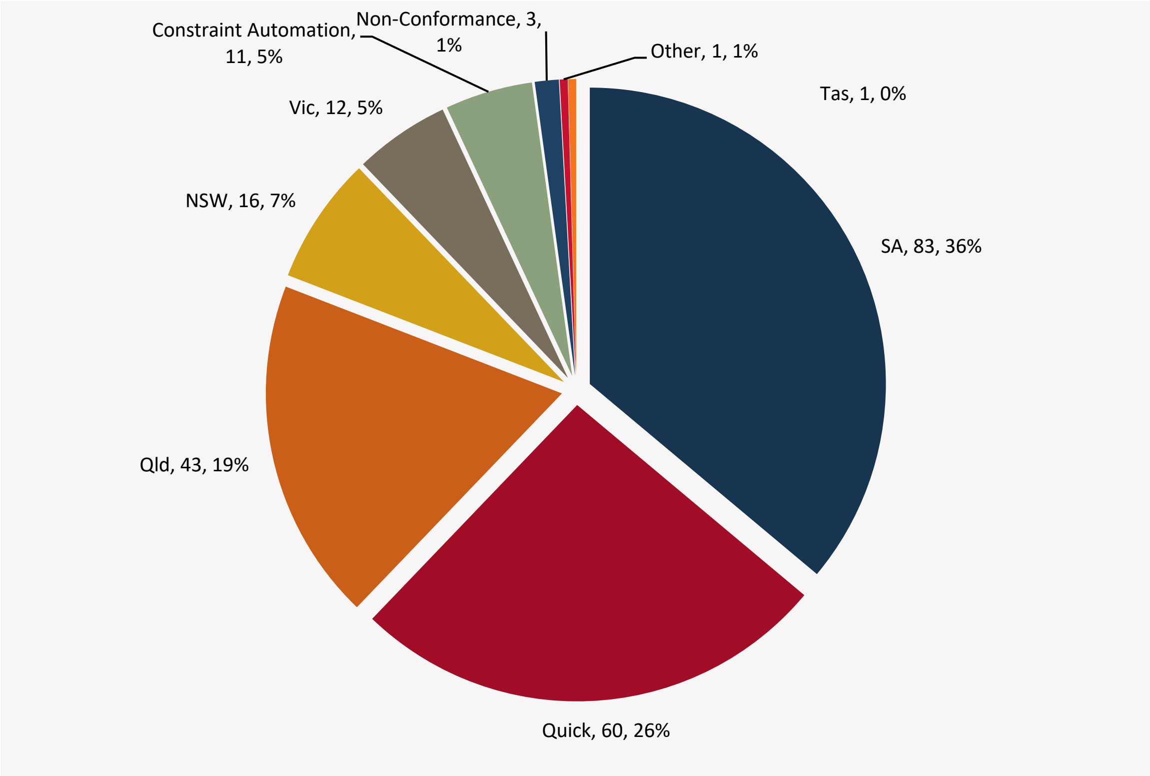
3.1 Constraint Equation Changes

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