Monthly Constraint Report

March 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.

Disclaimer

This document or the information in it may be subsequently updated or amended. This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the National Electricity Law, the National Electricity Rules, or any other applicable laws, procedures or policies. AEMO has made every effort to ensure the quality of the information in this document but cannot guarantee its accuracy or completeness.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this document:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this document; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this document, or any omissions from it, or for any use or reliance on the information in it.

Contents

Tables

Figures

1 Introduction

This report details constraint equation performance and transmission congestion related issues for March 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^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	6353 (529.41)	Voltage Stability
V_KIAMSF_0	Out = Kiamal Syncon, limit Kiamal solar farm to 0 MW	6177 (514.75)	Discretionary
Q_STR_7C2K_HASF_4	No limit to Haughton Solar Farm if Stan>=2+Cal>=1+Glad>=2+ (Stan+Cal+Glad) >=7+Kar>=2,NQLD>350&370(AVG),Ross_FN>150&170(AVG),Haughton Syncon is ON, Zero otherwise.	3312 (276.0)	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	2559 (213.25)	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	2223 (185.25)	Voltage Stability
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	2000 (166.66)	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1701 (141.75)	Thermal
N>>N-NIL_94K_1	Out= Nil, avoid O/L on Wellington Suntop Tee to Wellington 94K/1 132kV line on trip of Nil, Feedback	1546 (128.83)	Thermal
VT_ZERO	Vic to Tas on Basslink upper limit of 0 MW	1197 (99.75)	Interconnector Zero
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	1120 (93.33)	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	2,461,143	Thermal
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	1,736,656	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	1,718,863	Voltage Stability
N>>N-NIL_94K_1	Out= Nil, avoid O/L on Wellington Suntop Tee to Wellington 94K/1 132kV line on trip of Nil, Feedback	1,389,730	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	1,249,421	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	1,158,489	Thermal
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	1,078,307	Thermal
F_Q++ARTW_L6	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 6 sec Requirement	502,809	FCAS
F_Q++ARTW_L60	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 60 sec Requirement	495,579	FCAS
N^^Q_TW_330_BUS3_B1	Out= Tamworth No.3 330kV bus, NSW to Qld voltage stability limit for trip of Kogan Creek generator	474,753	Voltage Stability

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>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	62 (5.16)	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	37 (3.08)	Thermal
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	37 (3.08)	Thermal
S_DLBAT-G_ISL	Out= Yorke Peninsula 132kV network islanded (i.e. island formed between Hummocks-Androssan West- Dalrymple 132kV network), Dalrymple Battery (Gen Mode) islanded	37 (3.08)	Islanding - Unit
S_WP_ISL	Out= Yorke Peninsula 132kV network islanded (i.e. island formed between Hummocks-Androssan West- Dalrymple 132kV network), Wattle Pt WF islanded	31 (2.58)	Islanding - Unit
Q-MEWF_MVAR	Constraint to violate if Reactive power output of Mt Emerald Wind farm Solar farm is greater than +/10Mvar when it is limited at 0MW output, Swamp if MW >0 (DS only)	12 (1.0)	Unit Zero
Q-RGBSF_MVAR	Constraint to violate if Reactive power output of Rugby Run Solar farm is greater than +/10Mvar when it is limited at 0MW output, Swamp if MW >0 (DS only)	11 (0.91)	Unit Zero
V>V_NIL_RADIAL_10	Out = Nil, avoid O/L of Yallourn to Rowville No. 7 or No. 8 220 kV line for trip of the Yallourn to Rowville No. 8 or No. 7 220 kV line. Yallourn W1 on 220 kV side. Feedback	9 (0.75)	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; TG formulation only	7 (0.58)	Voltage Stability
Q-SMSF_MVAR	Constraint to violate if Reactive power output of Sun Metals Solar farm is greater than +/10Mvar when it is limited at 0MW output, Swamp if MW >0 (DS only)	7 (0.58)	Unit Zero

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
V>V_X_HWRO12_3	Constraint violated for 62 non-consecutive DIs with a max violation of 131.0 MW occurring on 04/03/2022 at 1245 hrs. Constraint violated due to Yallourn units 1-4 being limited by their ramp down rate immediately following a decrease in the dynamic rating of Yallourn to Rowville No. 5 220 kV line.
V>V_X_HWRO12_5	Constraint violated for 37 non-consecutive DIs with a max violation of 131.1 MW occurring on 04/03/2022 at 1245 hrs. Constraint violated due to Yallourn units 1-4 being limited by their ramp down rate immediately following a decrease in the dynamic rating of Yallourn to Rowville No. 6-8 220 kV lines.
V>V_X_HWRO12_1	Constraint violated for 37 non-consecutive DIs with a max violation of 126.5 MW occurring on 04/03/2022 at 1245 hrs. Constraint violated for same reason as above.
S_DLBAT-G_ISL	Constraint violated for 37 consecutive DIs on 27/03/2022 from 0715 hrs to 1015 hrs with a violation degree of 0.0015 MW. Constraint violated due to small non-zero SCADA values when Dalrymple Battery was not generating.
S_WP_ISL	Constraint violated for 31 DIs on 27/03/2022 including 30 consecutive DIs from 0430 hrs to 0705 hrs with a max violation of 0.26 MW occurring on 27/03/2022 at 1230 hrs. Constraint violated due to small non-zero SCADA values when Wattle Point Wind Farm was not generating.
Q-MEWF_MVAR	Constraint violated for 12 non-consecutive DIs with a violation degree of 0.001 MW. Constraint violated due to non-conforming of Mt Emerald Wind Farm.

Constraint Equation ID (System Normal Bold)	Description
Q-RGBSF_MVAR	Constraint violated for 11 non-consecutive DIs with a violation degree of 0.001 MW. Constraint violated due to non-conforming of Rugby Run Solar Farm.
V>V_NIL_RADIAL_10	Constraint violated for 9 non-consecutive DIs with a violation degree of 109.25 MW occurring on 04/03/2022 at 1245 hrs. Constraint violated due to Yallourn units 1-4 being limited by their ramp down rate immediately following a decrease in the dynamic rating of Yallourn to Rowville No. 7 and 8 220 kV lines.
N^N-LS_SVC	Constraint violated for 7 non-consecutive DIs with a max violation of 49.35 MW occurring on 24/03/2022 at 0610 hrs. Constraint violated due to competing requirements with the import limits on Terranora Interconnector which were set by constraint equations for outage of Directlink cables or Mudgeeraba to Terranora 110 kV line.
Q-SMSF_MVAR	Constraint violated for 7 non-consecutive DIs with a violation degree of 0.001 MW. Constraint violated due to non-conforming of Sun Metals Solar Farm.

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; TG formulation only	5764 (480.33)	-74.17 (68.93)
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	2425 (202.08)	157.47 (187.71)
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	1857 (154.75)	82.61 (1088.26)
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	1725 (143.75)	148.52 (-93.37)
VT_ZERO	T-V-MNSP1 Import	Vic to Tas on Basslink upper limit of 0 MW	1090 (90.83)	0.0 (0.0)
SVML^NIL_MH-CAP_ON	V-S-MNSP1 Import	Out=NIL, SA to Vic on ML upper transfer limit to manage voltage collapse at Monash (Note: applies when capacitor banks at Monash are available and I/S for switching.)	1031 (85.92)	-138.55 (-165.16)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	985 (82.08)	-57.97 (439.01)
F_Q++ARTW_L6	NSW1-QLD1 Import	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 6 sec Requirement	970 (80.83)	-198.29 (-407.21)
F_Q++ARTW_L6	N-Q-MNSP1 Import	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 6 sec Requirement	969 (80.75)	-43.82 (-101.62)
N^^Q_LS_VC_B1	NSW1-QLD1 Export	Out= Lismore SVC, avoid Voltage Collapse on loss of Kogan Creek	804 (67.0)	232.37 (364.27)

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

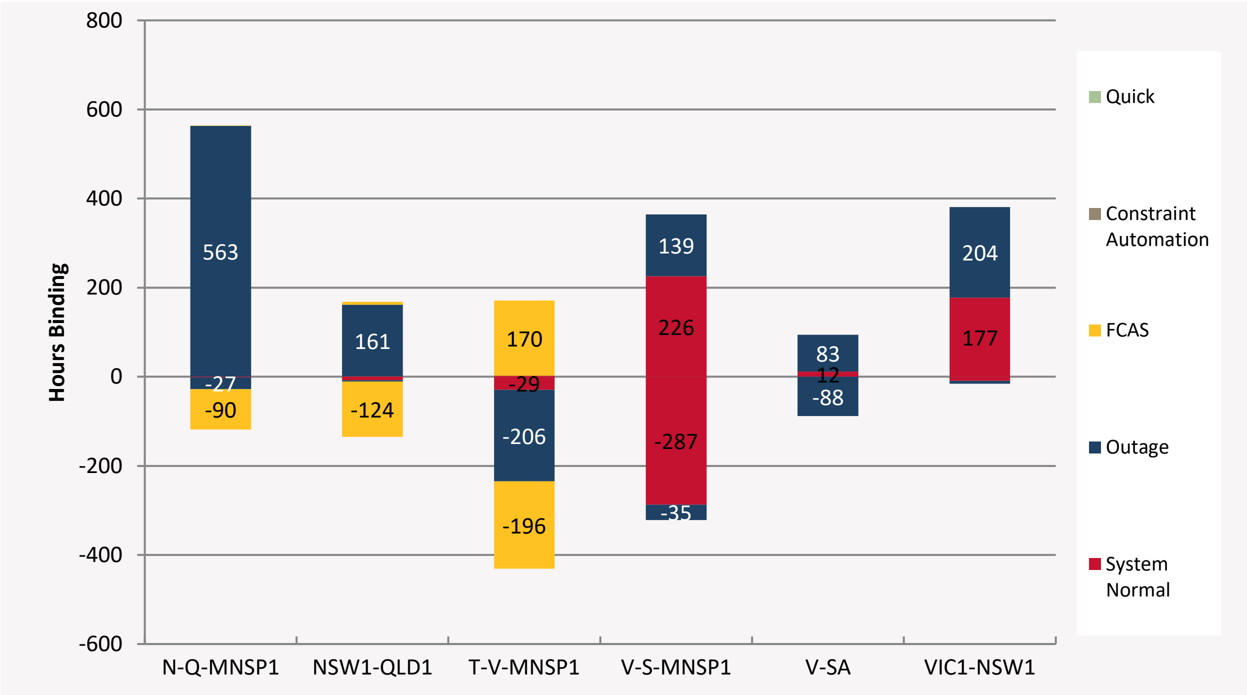
Non-real time constraint automation was not used.

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.

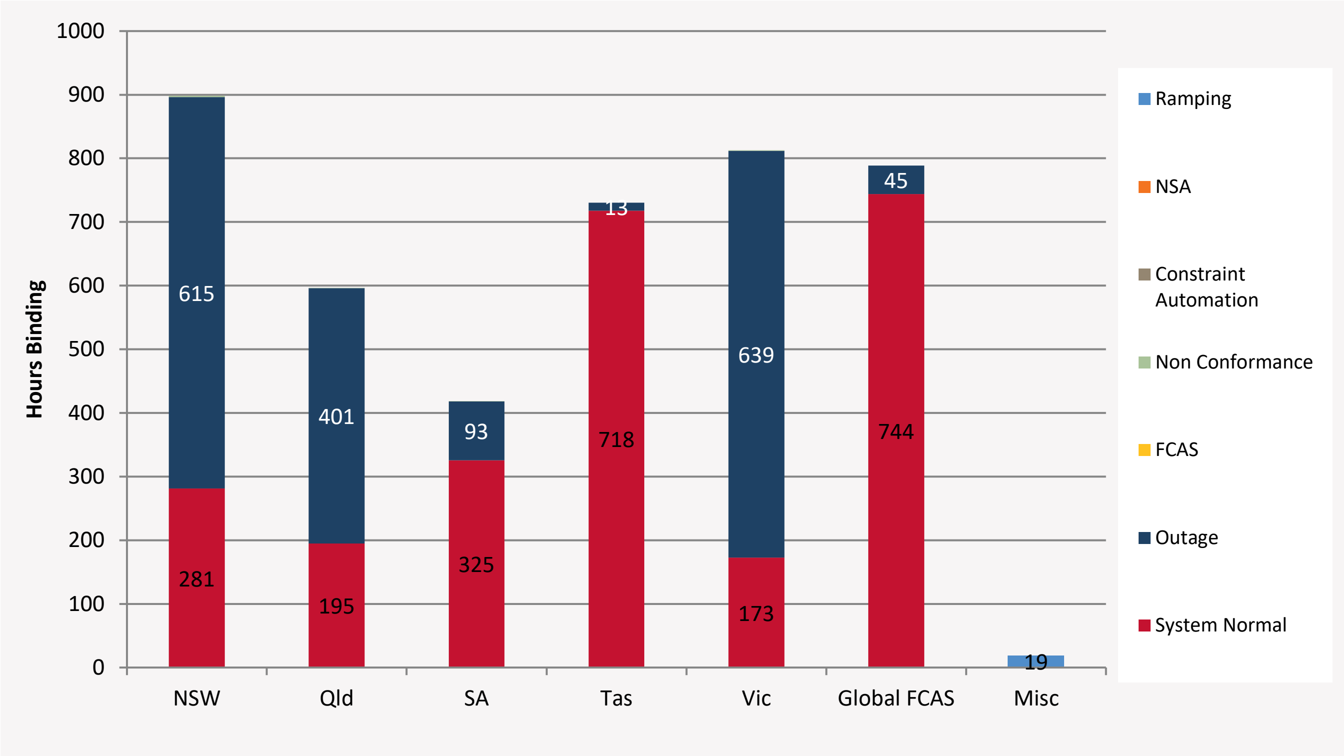
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

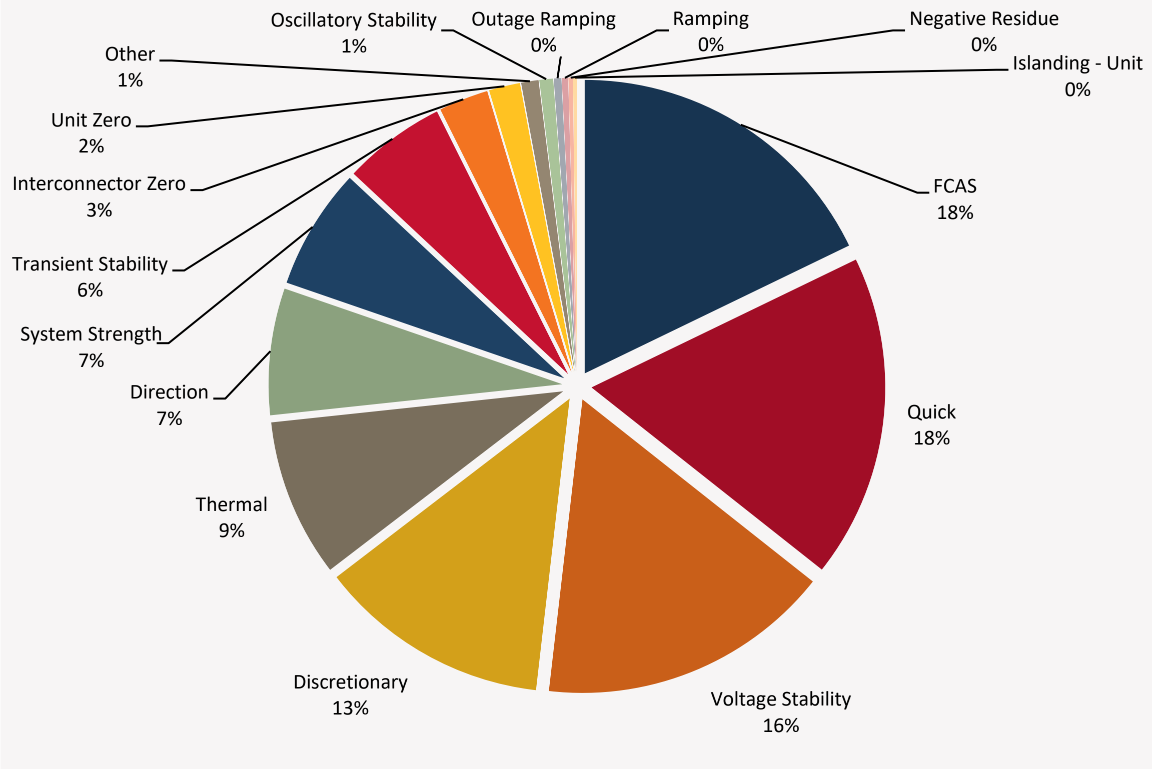
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

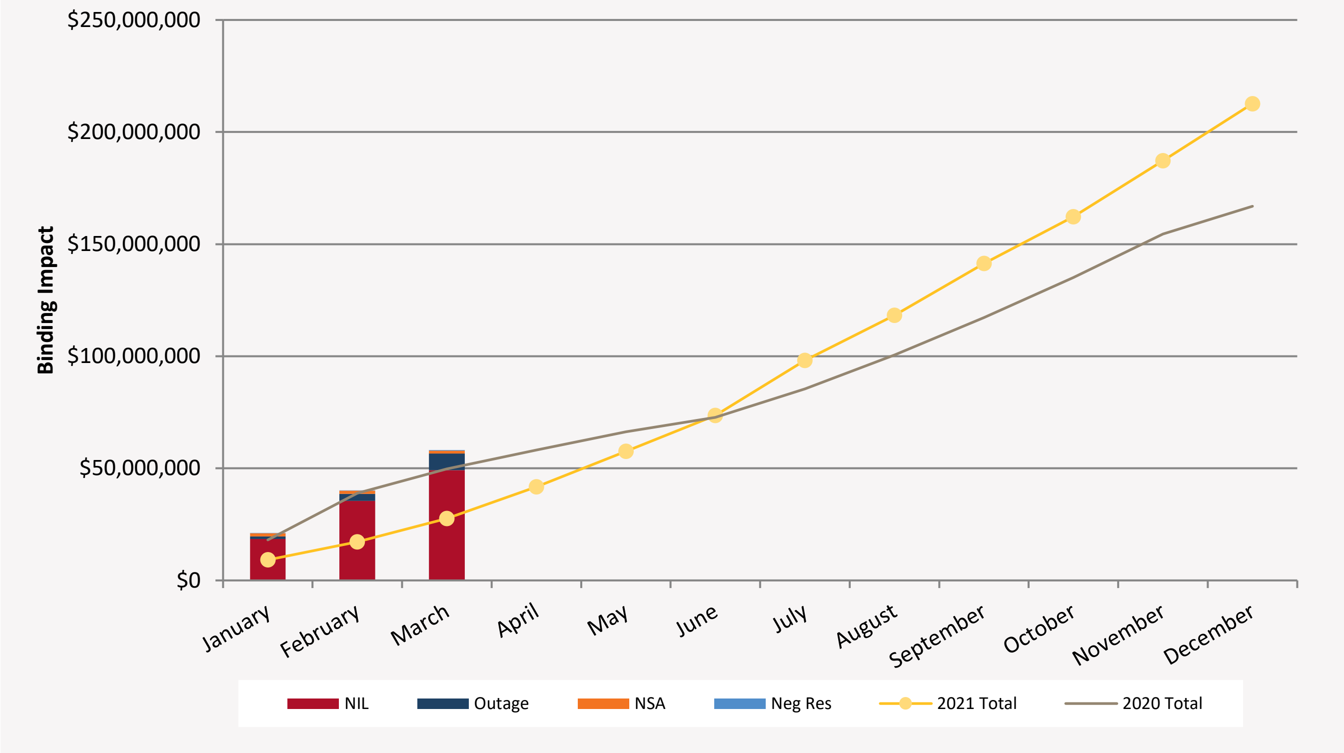
Figure 3 Binding by limit type



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; TG formulation only	1173	3,469% (164.79)	78.89% (23.78)
V::N_SMSC_S1	Out = one South Morang series capacitor, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 220 kV.	144	3,465% (409.82)	118.16% (74.8)
V::N_SMSC_S2	Out = one South Morang series capacitor, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	36	941% (327.62)	113.18% (71.76)
V>>V_DDSM_1	Out= Dederang to South Morang 330kV line, avoid O/L Ballarat to Bendigo 220kV line on trip of the remaining South Morang to Dederang 330kV line, Feedback	113	915% (293.42)	40.75% (70.28)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	74	350% (372.43)	16.49% (50.17)
S^NIL_MTM_VCS_STATUS	Out= Nil, upper limit for Mt Millar WF based on Mt Millar Voltage Control System (VCS) availability, (Note: MTM <=16 MW when VCS OFF; MTM<= 70 MW when VCS ON)	10	338% (54.)	311% (54.)
V::S_PWSE_MAXG	Out= Penola West - South East 132 kV line (Note: with both Black Range series caps I/S); Vic to SA Transient Stability limit for loss of the largest generator in SA.	11	135.08% (95.34)	43.53% (52.23)
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	21	119.27% (269.19)	68.18% (194.58)
N^^V_DDSM1	Out = Dederang to South Morang 330 kV line, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink or the parallel Dederang to South Morang 330kV line	10	106.92% (284.18)	34.55% (100.44)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

V::N_SMSC_S1: The Victorian export transient stability limits have been updated for the outage of one South Morang series capacitor, and this constraint has been archived.

V::N_SMSC_S2: Same as above.

V>>V_DDSM_1: Investigated and no improvement can be made to the constraint equation at this stage.

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

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

N^^V_DDSM1: 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.

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 March 2022.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Demand Response – Enel X NSW 3	1 March 2022	NSW	New registration for Wholesale Demand Response
Demand Response – Enel X SA 2	1 March 2022	SA	New registration for Wholesale Demand Response
Demand Response – Enel X Vic 24	1 March 2022	Victoria	New registration for Wholesale Demand Response
Demand Response – Enel X Vic 12	1 March 2022	Victoria	New registration for Wholesale Demand Response
Port Augusta Renewable Energy Park 210 MW Wind Farm	8 March 2022	SA	New Generator
Hunter Valley Gas Turbines	15 March 2022	NSW	Deregistered Generator
Metz Solar Farm	29 March 2022	NSW	New Generator
Demand Response – Enel X NSW 34	29 March 2022	NSW	New registration for Wholesale Demand Response
Demand Response – Enel X NSW 32	29 March 2022	NSW	New registration for Wholesale Demand Response
Demand Response – Enel X NSW 31	29 March 2022	NSW	New registration for Wholesale Demand Response
Beaconsfield South to Rookwood Road 330 kV line	31 March 2022	NSW	New Transmission Line

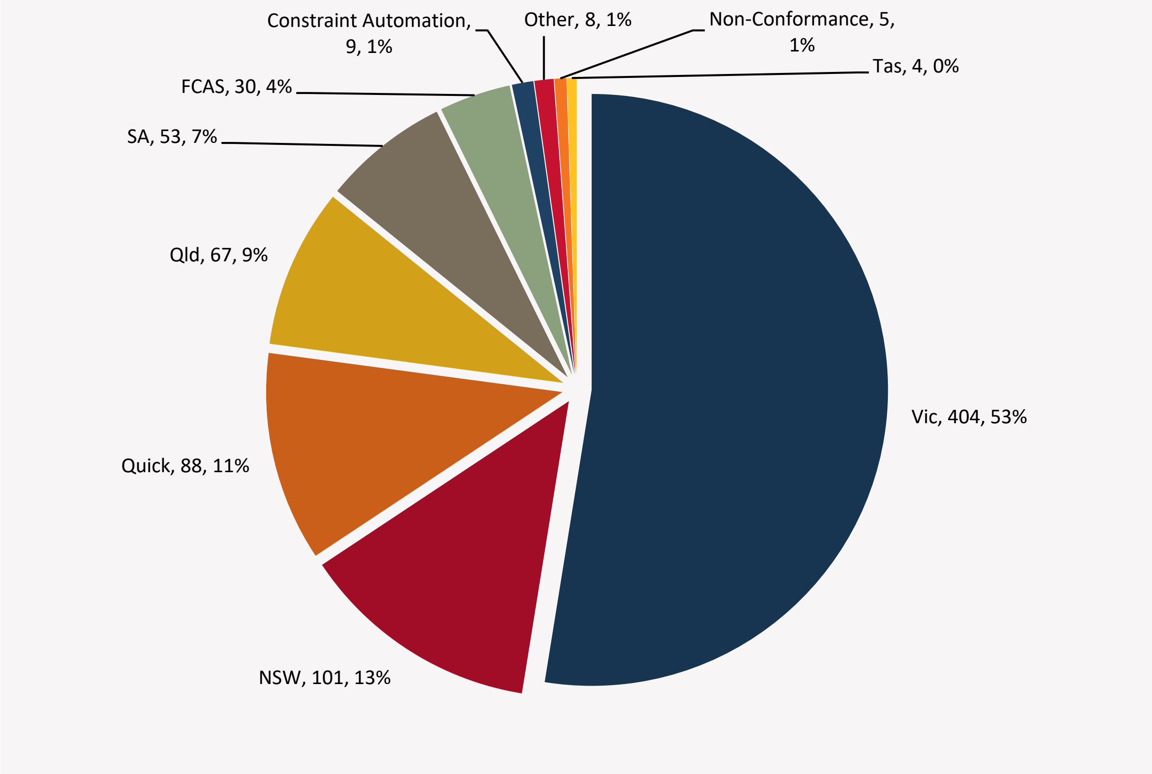
3.1 Constraint Equation Changes

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