Monthly Constraint Report

October 2021

A report for the National Electricity Market

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 2021. 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
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	3213 (267.75)	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.	2959 (246.58)	Transient Stability
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	2158 (179.83)	Voltage Stability
N^^N_NIL_2	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	2070 (172.5)	Voltage Stability
Q>NIL_YLMR	Out= Nil, avoid overload on 110kV feeders between Yarranlea and Middle Ridge(733/1 and 734/1), Feedback	1937 (161.41)	Thermal
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1654 (137.83)	Thermal
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1474 (122.83)	Voltage Stability
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	1412 (117.66)	Unit Zero
T_MRWF_FOS	Limit Musselroe wind farm due to upper limit on Tasmanian generator events. Limit is 153 MW (effective 144 MW at the connection point at Derby)	1212	Other

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
		(101.0)	
Q_OAKEY1SF_ZERO	Oakey 1 Solar Farm upper limit of 0 MW	1148 (95.66)	Unit Zero

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_2	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	3,166,769	Voltage Stability
N>>N-NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	1,785,029	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	1,645,098	Thermal
Q_OAKEY1SF_ZERO	Oakey 1 Solar Farm upper limit of 0 MW	1,195,249	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	1,158,117	Voltage Stability
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	988,013	Thermal
S-X_2DV+2RB_STRGHT_1	Out = 2 x Davenport + 2 x Robertstown synchronous condensers O/S, Upper limit (1300 to 1750 MW) for SA ASG for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	641,570	System Strength
F_Q++ARTW_L60	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 60 sec Requirement	569,150	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	550,353	Voltage Stability
N>N-NIL_PK_TX2	Out= Nil, avoid O/L Parkes TX2 132/66kV transformer on trip of Nil, Feedback	529,734	Thermal

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.

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.

Table 3 Top 10 violating constraint equations

Table 1 – Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Limit Type
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	21 (1.75)	Negative Residue
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	7 (0.58)	Network Support
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	7 (0.58)	FCAS
N_BROKENH1_0INV	Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	7 (0.58)	System Strength
F_Q++ARTW_L6	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 6 sec Requirement	5 (0.41)	FCAS
F_Q++ARTW_L5	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 5 min Requirement	4 (0.33)	FCAS
NSA_Q_GSTONE34_150	Gladstone 3+4 >= 150 for Network Support Agreement	3 (0.25)	Network Support
F_Q++ARTW_L60	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 60 sec Requirement	1 (0.08)	FCAS
F_Q++MUTW_L5	Out = Muswellbrook to Tamworth (88) line, Qld Lower 5 min Requirement	1 (0.08)	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	1 (0.08)	FCAS

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Table 2 – Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
NRM_QLD1_NSW1	Constraint equation violated for 21 non-consecutive Dis where max violation of 197.57 MW occurred on 1/10/2021 at 1045 hrs. Constraint equation violation occurred due to competing requirements with the export limits which were set by N>>Q_LDMU_B, N>N-NIL_LSDU, F_Q++LDMU_R6, F_Q++LDMU_R5, N^^Q_MUTW_1_B1, N^^Q_TW_330_BUS1_B1, and Q>>CPST_CLWU_LCCP

Constraint Equation ID (System Normal Bold)	Description
NSA_V_NPSD_100	Constraint equation violated for 7 consecutive DIs on 31/10/2021 from 0950 hrs to 1020 hrs with max violation of 85 MW at 0950 hrs. Constraint equation violation occurred due to Newport unit being limited by its start-up profile.
F_T_AUFLS2_R6	Constraint equation violated for 7 non-consecutive Dis with max violation of 13.58 MW on 12/10/2021 at 1350 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
N_BROKENH1_0INV	Constraint equation violated for 7 DIs on 31/10/2021, 6 of which were consecutive, with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit.
F_Q++ARTW_L6	Constraint equation violated for 5 non-consecutive Dis on 16/10/2021 with max violation of 34.82 MW occurring at 1030 hrs. Constraint equation violation occurred due to Queensland lower 6 second availability being less than the requirement.
F_Q++ARTW_L5	Constraint equation violated for 4 DIs on 16/10/2021 with max violation of 46.23 MW occurring at 1030 hrs. Constraint equation violation occurred due to Queensland lower 5 minute availability being less than the requirement.
NSA_Q_GSTONE34_150	Constraint equation violated for 3 DIs on 18/10/2021 at 1110 hrs, 1115 hrs, and 1120 hrs with violation degree of 10 MW. Constraint equation violation occurred due to Gladstone units 3+4 availability being less than the requirement.
F_Q++ARTW_L60	Constraint equation violated for 1 DI on 16/10/2021 at 1030 hrs with violation of 24.53 MW. Constraint equation violation occurred due to Queensland lower 60 second availability being less than the requirement.
F_Q++MUTW_L5	Constraint equation violated for 1 DI on 16/10/2021 at 1030 hrs with violation of 9.26 MW. Constraint equation violation occurred due to Queensland lower 5 minute availability being less than the requirement.
F_T+NIL_WF_TG_R6	Constraint equation violated for 1 DI on 07/10/2021 at 1255 hrs with max violation of 8.42 MW. Constraint equation violation occurred due to Tasmania raise 6 second availability being less 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)
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	3119 (259.92)	154.2 (186.88)
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	1895 (157.92)	177.54 (832.5)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1418 (118.17)	287.43 (459.01)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N_X_MBTE_3A	N-Q-MNSP1 Export	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	1412 (117.67)	-21.77 (11.9)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1401 (116.75)	721.31 (1034.11)
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	1288 (107.33)	145.14 (-150.0)
N^^N_NIL_2	V-S-MNSP1 Import	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	1241 (103.42)	143.74 (-173.53)
N_X_MBTE_3B	N-Q-MNSP1 Import	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	919 (76.58)	-4.83 (-39.0)
V^^N_MSUT_1	VIC1-NSW1 Export	Out = Murray to Upper Tumut (65), avoid voltage collapse around Murray for loss of all APD potlines	847 (70.58)	535.6 (784.48)
VT_ZERO	T-V-MNSP1 Import	Vic to Tas on Basslink upper limit of 0 MW	837 (69.75)	0.0 (0.0)

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 3 – Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_BRIS_50737673	09/10/2021 11:05 to 09/10/2021 16:00	This constraint automation was created to manage thermal overload of Murray – Lower Tumut 66 330 kV for contingent trip of Lower Tumut – Wagga 051 330 kV line during prior outages of Murray – Upper Tumut 65 330 kV and Wagga – Gadara 993 132 kV lines.
CA_BRIS_507E31FE	17/10/2021 14:55 to 18/10/2021 07:40	This constraint automation was created to manage thermal overload of Murray – Lower Tumut 66 330 kV for contingent trip of Lower Tumut – Wagga 051 0330 kV line due to VNI fluctuating over target.

2.5.1 Further Investigation

CA_BRIS_50737673: A new multiple outage constraint, N-X_MSUT_993_99P, has been created to manage this scenario for future outages.

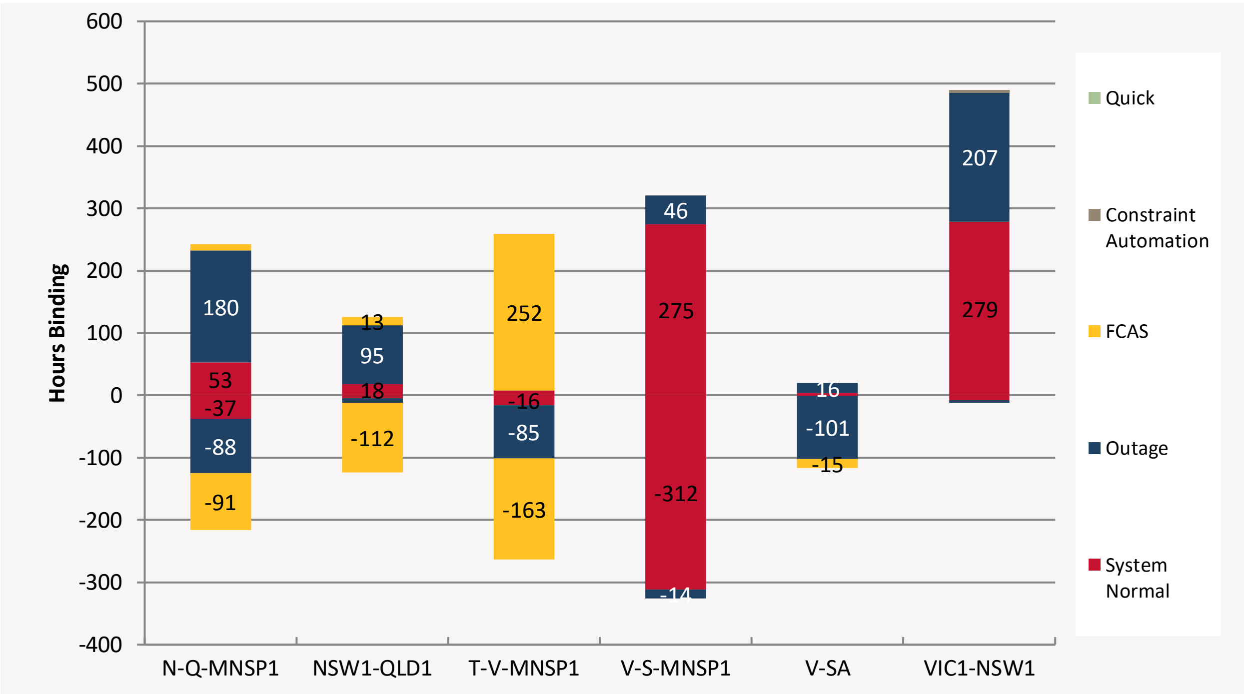
CA_BRIS_507E31FE: The operating margin of the V>>N-MSUT_1 constraint equation has been increased to 50 MW to manage this scenario in the future.

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.

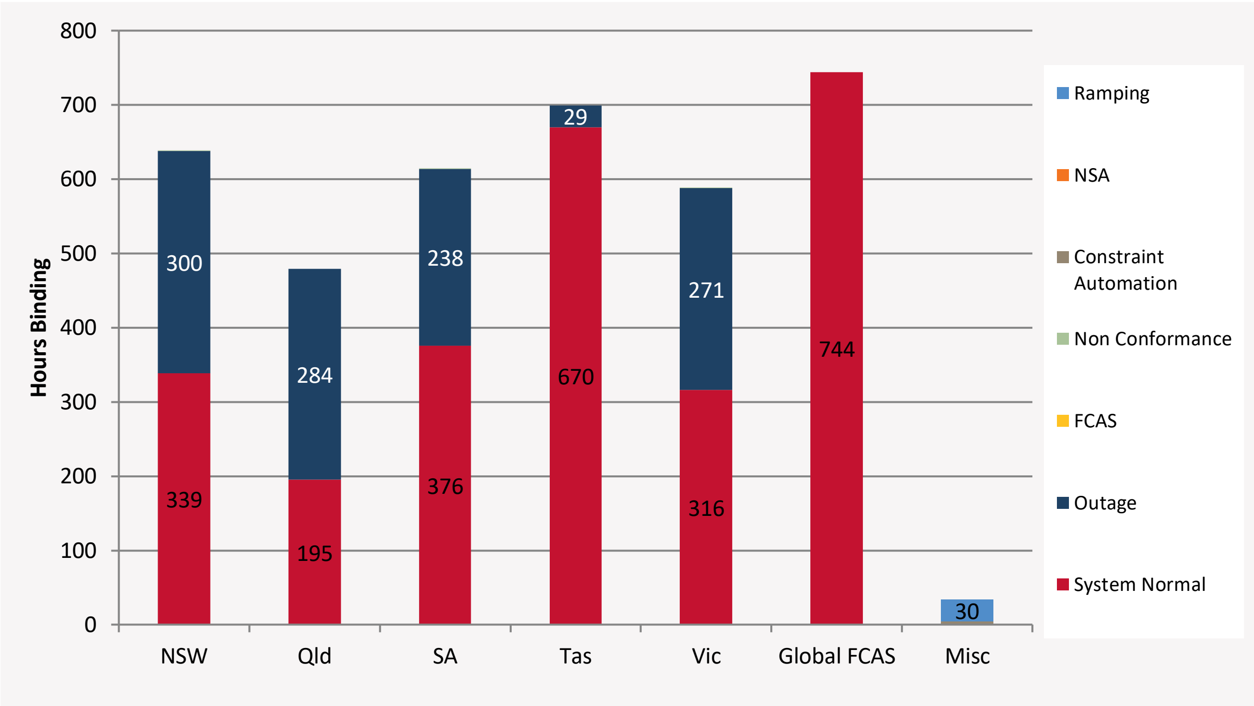
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

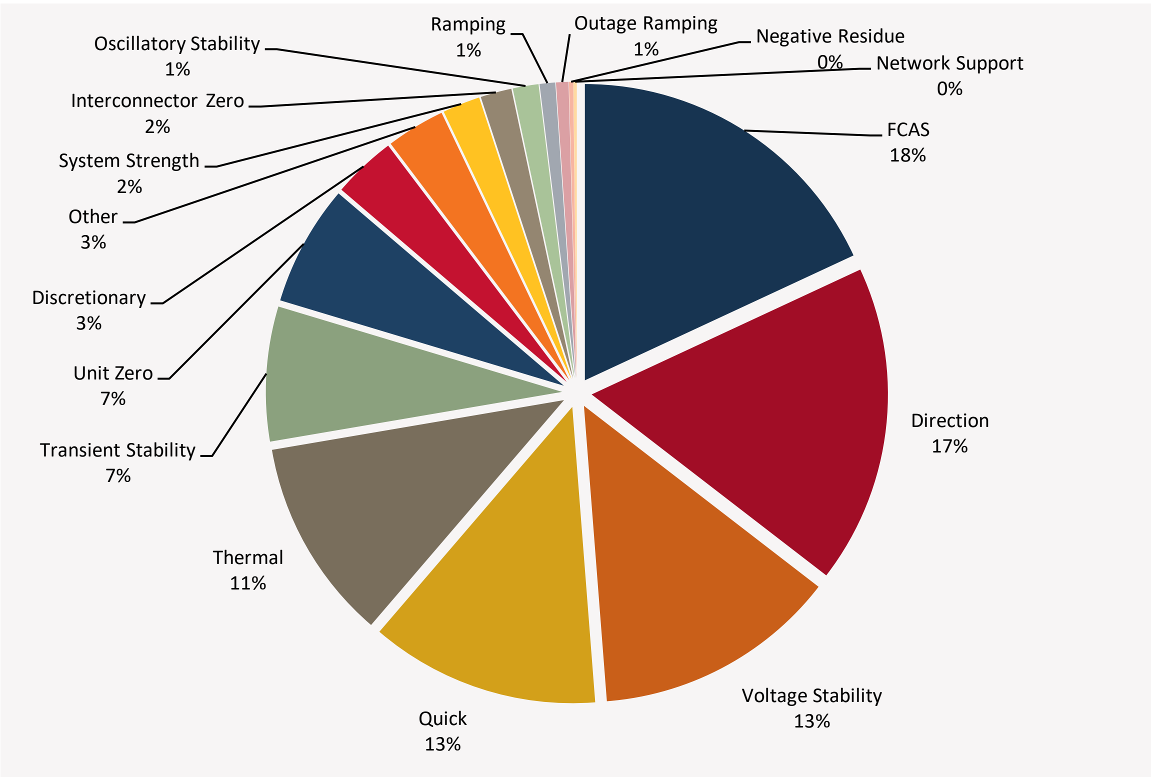
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for October 2021 that the different types of constraint equations bound.

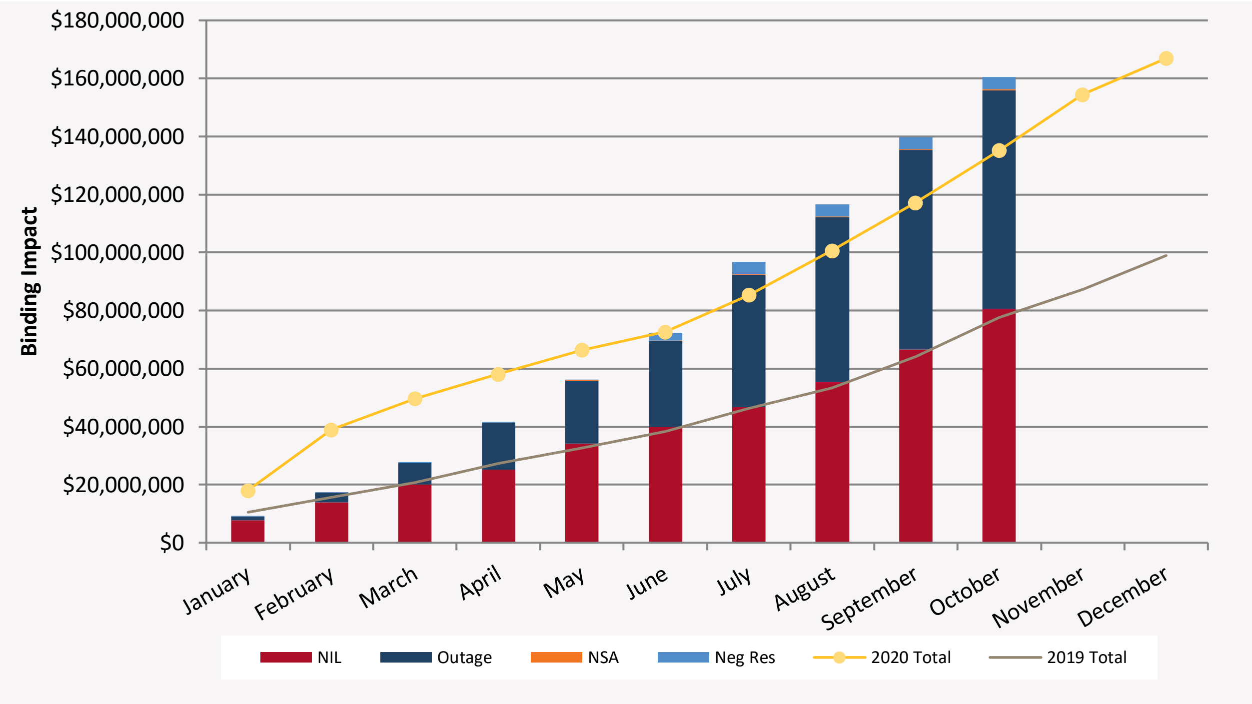
Figure 3 Binding by limit type



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_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	3	17,241% (144.96)	6,640% (106.85)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	288	2,980% (38.3)	112.83% (6.62)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_SMF2_V1	Out = South Morang F2 500/330kV txfmr, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	12	2,720% (310.41)	319% (158.81)
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.	47	2,470% (9,474)	290% (469.88)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	189	2,020% (45.5)	187% (10.34)
S>NIL_HUWT_STBG2	Out = Nil; Limit Snowtown WF generation to avoid Snowtown - Bungama line OL on loss of Hummocks - Waterloo line.[Note: Wattle PT trips when generating >=80 MW when Dalymple Battery (i.e. both Gen and Load component) is I/S]	79	169% (112.12)	32.1% (31.76)
S>RBMW4+TX_NIL_RBTX 1	Out= Robertstown - MWP4 + one 275/132kV RBTX O/S, avoid O/L of remaining Robertstown 275/132kV TX on Nil trip, Feedback	30	133.% (170.37)	61.36% (76.4)
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	6	132.61% (307.68)	83.12% (186.46)
V::N_DDSM_V1	Out = Dederang to South Morang 330kV line, prevent transient instability for fault and trip of the parallel Dederang to South Morang 330kV line, VIC accelerates, Yallourn W G1 on 220 kV.	17	107.06% (270.5)	36.31% (102.5)
NRM_NSW1_VIC1	Negative Residue Management constraint for NSW to VIC flow	12	100.% (9,408)	99.53% (9,148)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N_X_MBTE_3A: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_SMF2_V1: 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.

N_X_MBTE_3B: Investigated and no improvement can be made to the constraint equation at this stage.

S>NIL_HUWT_STBG2: Investigated and no improvement can be made to the constraint equation at this stage.

S>RBMW4+TX_NIL_RBTX1: 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

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 for October 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Hillston Solar Farm	5 October 2021	NSW1	New Generator
Demand Response – Enel X NSW	24 October 2021	NSW1	New registration for Wholesale Demand Response
Demand Response – Enel X Vic	24 October 2021	VIC1	New registration for Wholesale Demand Response
Wallgrove Battery - Load Component	26 October 2021	NSW1	New Battery
Wallgrove Battery - Gen Component	26 October 2021	NSW1	New Battery

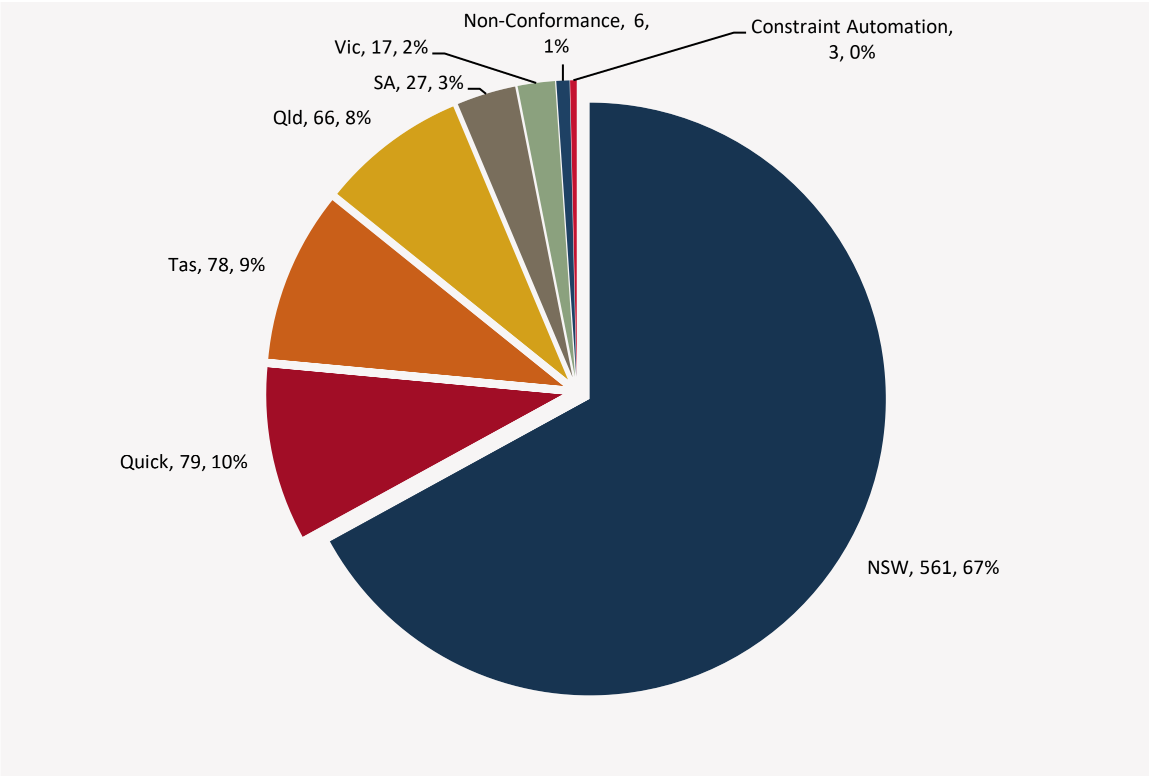
3.1 Constraint Equation Changes

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