Monthly Constraint Report

December 2020

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 December 2020. 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)	Change Date
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)	2110 (175.83)	1/01/2020
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	1649 (137.41)	4/12/2020
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	1374 (114.5)	29/09/2020
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1334 (111.16)	13/11/2020
V>V_NIL_17	Out = NIL, prevent pre-contingent overload of Wemen 220/66 kV txfmr, flow from 66 kV to 220 kV, feedback	1292 (107.66)	29/09/2020
S_NIL_STRENGTH_1	Upper limit (1300 to 1750 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	1277 (106.41)	19/08/2020
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse for contingency trip of Bendigo-Kerang 220kV line in NW Victoria	1123 (93.58)	4/12/2020
V^^N_HWSM_1	Out = Hazelwood to South Morang 500kV line, avoid voltage collapse around Murray for loss of all APD potlines	1104 (92.0)	13/11/2020
N>>N-NIL_94T_947	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Wellington to Orange North (947), Feedback	903	10/12/2020

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
		(75.25)	
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	660 (55.0)	9/12/2019

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	Change Date
S_NIL_STRENGTH_1	Upper limit (1300 to 1750 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online.	1,224,933	19/08/2020
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	1,021,605	4/12/2020
V>V_NIL_17	Out = NIL, prevent pre-contingent overload of Wemen 220/66 kV txfmr, flow from 66 kV to 220 kV, feedback	1,003,626	29/09/2020
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)	624,642	1/01/2020
Q>NIL_COLNVSF1	Out = Nil, Limit Collinsville Solar Farm to thermal rating of Powerlink's RMU	524,255	5/11/2019
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	502,621	29/09/2020
V_DUNDWF1_ZERO	Dundonnell wind farm 1 upper limit of 0 MW	416,721	29/11/2019
V_DUNDWF3_ZERO	Dundonnell wind farm 3 upper limit of 0 MW	403,909	29/11/2019
V_DUNDWF2_ZERO	Dundonnell wind farm 2 upper limit of 0 MW	388,170	29/11/2019
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse for contingency trip of Bendigo-Kerang 220kV line in NW Victoria	357,320	4/12/2020

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

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	21 (1.75)	21/12/2018
V_KIAMAL_0INV	Constraint to violate if Kiamal Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	20 (1.66)	30/07/2020
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	9 (0.75)	23/12/2020
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	8 (0.66)	2/12/2016
V_KARSF_8INV	Limit Karadoc Solar Farm upper limit to 0 MW if number of inverter available exceed 8. Constraint swamp out if number of inverter available not exceed 8. This is to manage voltage oscillation. DS only	8 (0.66)	11/08/2020
V^SML_BAWB_3	Out = Ballarat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	5 (0.41)	7/01/2019
V_ARWF_FSTTRP_5	Out= Ararat WF fast tripping scheme (disabled), Limit Ararat Windfarm upper limit to 5 MW, DS only. Swamp out if the scheme is in service (enabled).	3 (0.25)	3/05/2019
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	3 (0.25)	23/09/2020
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	3 (0.25)	4/05/2018
V_GANNSF_12INV	Limit Gannawarra Solar Farm upper limit to 0 MW if number of inverter available exceed 12. Constraint swamp out if number of inverter available not exceed 12. This is to manage voltage oscillation. DS only	3 (0.25)	11/08/2020

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
NSA_V_NPSD_100	Constraint equation violated for 21 non-consecutive DIs on 03/12/2020, 24/12/2020, 25/12/2020, 27/12/2020 and 28/12/2020 with max violation of 85 MW occurring on 03/12/2020 at 0105 hrs, 0110 hrs and 0115 hrs, and on 25/12/2020 at 0335 hrs. Constraint equation violation occurred due to Newport PS being limited by its start-up profile.
V_KIAMAL_0INV	Constraint equation violated for 20 non-consecutive intervals on 04/12/2020 and 06/12/2020, 19 of which were consecutive on 04/12/2020 from 1005 hrs to 1135 hrs, with violation degree of 0.01 MW. Constraint equation violated due to Kiamal Solar Farm exceeding its inverter limit.

Constraint Equation ID (System Normal Bold)	Description
F_T+NIL_WF_TG_R6	Constraint equation violated for 9 non-consecutive DIs on 01/12/2020, 02/12/2020, 05/12/2020 and 07/12/2020 with max violation of 51.14 MW on 05/12/2020 at 2125 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 8 DIs on 10/12/2020 and 14/12/2020 with max violation of 20.73 MW occurring on 10/12/2020 at 0815 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
V_KARSF_8INV	Constraint equation violated for 8 non-consecutive DIs on 04/12/2020 and 05/12/2020 with violation degree of 0.001 MW. Constraint equation violated due to Karadoc Solar Farm exceeding its inverter limit.
V^SML_BAWB_3	Constraint equation violated for 5 DIs on 04/12/2020 with max violation of 11.93 MW at 1410 hrs. Constraint equation violation occurred due to competing requirements with the import limit which were set by I_CTRL_ISSUE_ML.
V_ARWF_FSTTRP_5	Constraint equation violated for 3 DIs on 01/12/2020 at 0810 hrs, 0815 hrs and 1225 hrs with max violation of 116.3 MW occurring at 1225 hrs. Constraint equation violated due to Ararat wind Farm non-conforming.
NRM_QLD1_NSW1	Constraint equation violated for 3 DIs on 04/12/2020 at 1445 hrs, 1450 hrs and 1500 hrs with max violation of 76.81 MW occurring at 1500 hrs. Constraint equation violation occurred due to competing requirements with the export limit which were set by F_Q++MUTW_R5 and Q>>NIL_CLWU_RGLC.
F_T_AUFLS2_R6	Constraint equation violated for 3 DIs on 01/12/2020 at 2215 hrs, 10/12/2020 at 1520 hrs and 18/12/2020 at 1015 hrs with max violation of 2.26 MW occurring on 01/12/2020 at 2215 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
V_GANNSF_12INV	Constraint equation violated for 3 DIs on 04/12/2020 at 1005 hrs, 1010 hrs and 1015 hrs with violation degree of 0.001 MW. Constraint equation violated due to Gannawarra Solar Farm exceeding its inverter limit.

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_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	1385 (115.42)	121.22 (-149.25)
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	1324 (110.33)	-320.69 (-459.0)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1269 (105.75)	-53.74 (180.38)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1230 (102.5)	736.31 (942.56)

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	1173 (97.75)	156.66 (191.71)
F_MAIN++APD_TL_L5	T-V-MNSP1 Import	Out = Nil, Lower 5 min Service Requirement for a Mainland Network Event-loss of APD potlines due to undervoltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS	1108 (92.33)	-385.52 (-459.0)
V^^N_HWSM_1	V-S-MNSP1 Export	Out = Hazelwood to South Morang 500kV line, avoid voltage collapse around Murray for loss of all APD potlines	1003 (83.58)	-56.68 (183.06)
V^^N_HWSM_1	VIC1-NSW1 Export	Out = Hazelwood to South Morang 500kV line, avoid voltage collapse around Murray for loss of all APD potlines	981 (81.75)	719.36 (883.85)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	969 (80.75)	60.4 (459.0)
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	961 (80.08)	-442.46 (-459.01)

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

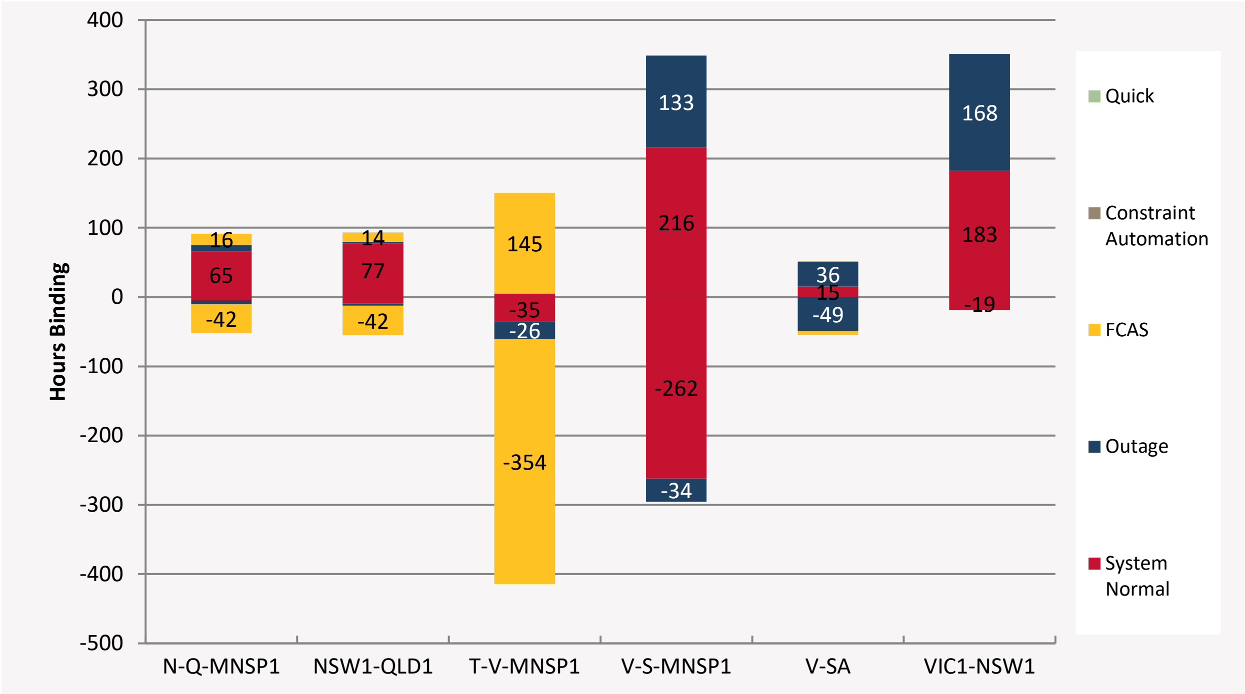
Non-real time constraint automation was not used.

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.

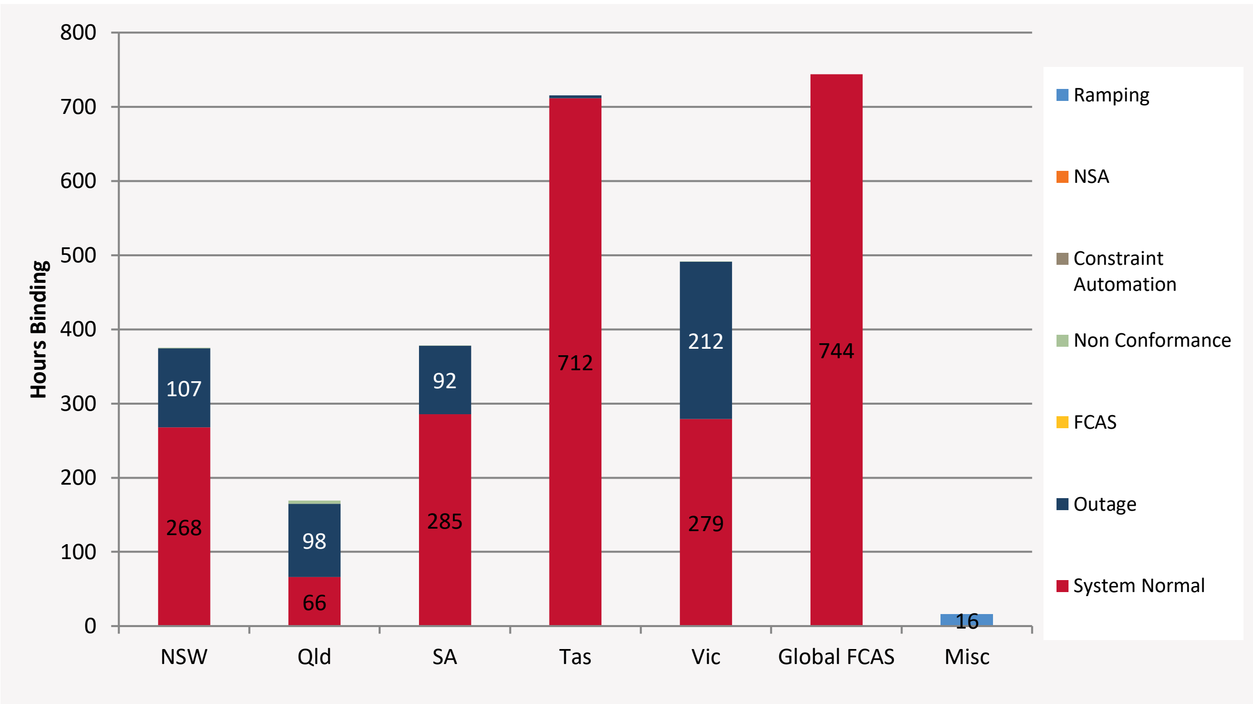
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

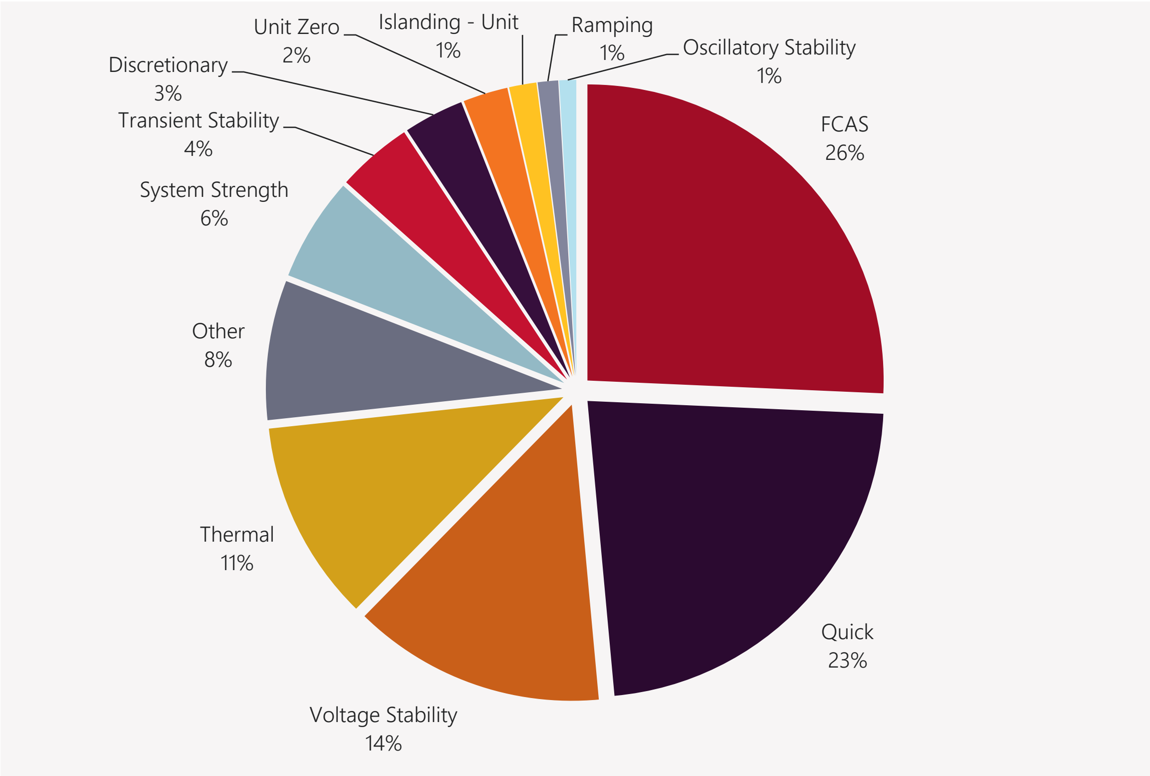
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for December 2020 that the different types of constraint equations bound.

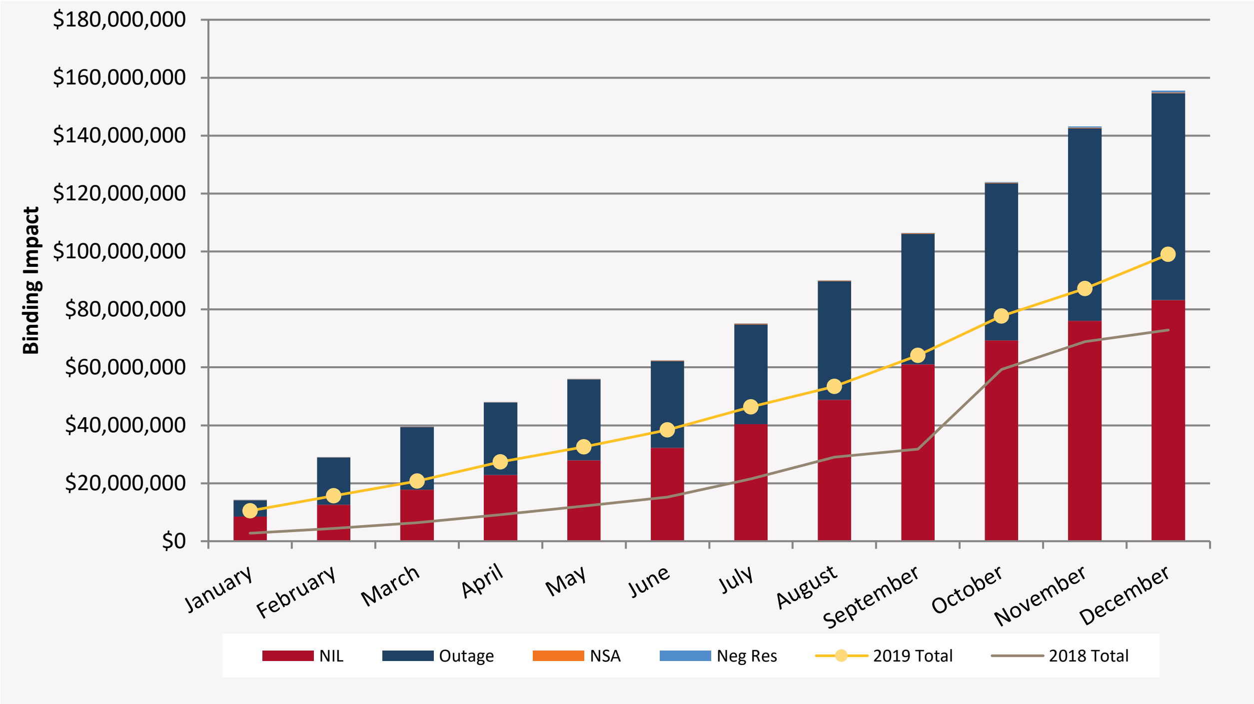
Figure 3 Binding by limit type



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::N_BYPASS_HW_SY_S4	Out=Three SMTS 500kV CBs for HWTS & SYTS line(#1 or #2), bypass for HWTS to SYTS direct line, avoid trans. instability for trip of a HWTS-SYTS or HWTS-SMTS 500kV line, SA accelerates, Basslink VIC->TAS. YPS #1 on 500kV. Only applied during Heywood SA->VIC	5	6,175% (220.45)	1,274% (94.06)
V::N_HWSM_V2	Out = Hazelwood to South Morang OR Hazelwood to Rowville 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	58	5,883% (220.68)	247% (66.55)
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.	93	4,033% (9,489)	266% (662)
V::N_HWSM_V1	Out = Hazelwood to South Morang OR Hazelwood to Rowville 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	9	608% (147.5)	87.28% (46.79)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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]	80	249% (137.23)	55.68% (45.78)
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.	157	212% (359.6)	48.3% (134.77)
V^SML_BAWB_3	Out = Ballarat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	6	141.01% (35.56)	76.47% (30.48)
V>>V_NIL_14	Out= Nil, avoid O/L Wemen to Kerang 220kV line on trip of Horsham to Murra Warra to Kiamal 220kV line (this trips Murra Warra WF), Feedback	14	111.53% (310.31)	21.37% (78.25)
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	156	108.29% (62.27)	45.37% (25.44)
NRM_NSW1_VIC1	Negative Residue Management constraint for NSW to VIC flow	14	100.% (9,483)	98.7% (9,158)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_HWSM_V2: Investigated and no improvement can be made to the constraint equations 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::N_HWSM_V1: 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.

T::T_NIL_1: Investigated and no improvement can be made to the constraint equation at this stage.

V^SML_BAWB_3: Investigated and no improvement can be made to the constraint equation at this stage.

V>>V_NIL_14: 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>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.

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 December 2020.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Jemalong Solar Project	2 December 2020	NSW1	New Generator
Middlemount Solar Farm	8 December 2020	QLD1	New Generator
Bango 973 Wind Farm	15 December 2020	NSW1	New Generator
Cohuna Solar Farm	22 December 2020	VIC1	New Generator
Glenrowan West Solar Farm	22 December 2020	VIC1	New Generator

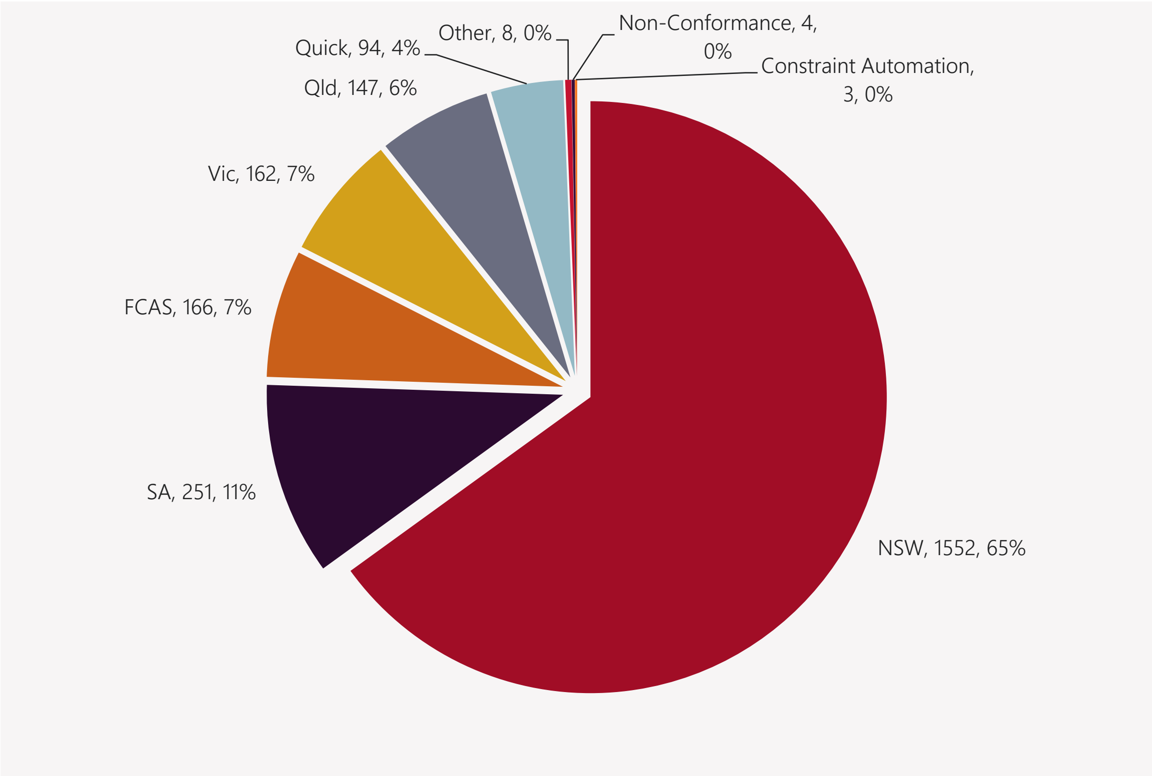
3.1 Constraint Equation Changes

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