AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

August 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 August 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
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	4127 (343.91)	25/11/2013
Q_NIL_STRGTH_MEWF	Out = Nil, limit Mt Emerald WF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	2489 (207.41)	5/08/2020
Q_NIL_STRGTH_HAUSF	Out = Nil, limit Haughton SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	2232 (186.0)	5/08/2020
Q^^NIL_QNI_SRAR	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	1437 (119.75)	18/06/2019
Q_NIL_STRGTH_SMSF	Out = Nil, limit Sun Metal SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	931 (77.58)	5/08/2020
V_BANSF_BBD_60	Out = Nil, Limit Bannerton SF upper limit to 60 MW if Boundary Bend (BBD) loading is less than 10 MW, DS only. Swamp out if BBD loading is 10 MW or above.	768 (64.0)	16/08/2019
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	755 (62.91)	20/12/2016

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	677 (56.41)	29/05/2020
V_BULGANAWF_FLT_0	Limit Bulgana Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	546 (45.5)	19/07/2019
NSA_Q_GSTONE34_150	Gladstone 3+4 >= 150 for Network Support Agreement	431 (35.91)	7/10/2015

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
Q_NIL_STRGTH_MEWF	Out = Nil, limit Mt Emerald WF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	2,395,014	5/08/2020
Q_NIL_STRGTH_HAUSF	Out = Nil, limit Haughton SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	2,182,746	5/08/2020
Q_MEWF1_ZERO	Mt Emerald Wind Farm upper limit of 0 MW	863,024	19/07/2018
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.	759,279	19/08/2020
V_BANSF_BBD_60	Out = Nil, Limit Bannerton SF upper limit to 60 MW if Boundary Bend (BBD) loading is less than 10 MW, DS only. Swamp out if BBD loading is 10 MW or above.	703,792	16/08/2019
N_STWF1_ZERO	Silverton wind farm upper limit of 0 MW and all wind turbines disconnected.	696,896	10/08/2020

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.

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Change Date
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	692,348	29/05/2020
V_BULGANAWF_FLT_0	Limit Bulgana Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	582,196	19/07/2019
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)	419,284	1/01/2020
Q_LILYSF1_ZERO	Lilyvale Solar Farm upper limit of 0 MW	354,226	20/08/2018

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
N_BKHSF_40INV	Limit Broken Hill Solar Farm upper limit to 0 MW if number of inverter available exceed 40. Constraint swamp out otherwise. DS only	14 (1.16)	13/07/2020
V_MURRAWRWF_30WT	Limit Murra Warra Wind Farm upper limit to 0 MW if number of turbine ON exceed 30. Constraint swamp out if number of turbine ON not exceed 30. This is to manage voltage oscillation. DS only	11 (0.91)	13/07/2020
DSNAP_V::S_NIL_MAXG1	DATASNAP NEVER TO BIND 10000 swamp; TESTING Out = Nil(Note: with both Black Range series capacitors I/S); Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available).	8 (0.66)	15/04/2020
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	7 (0.58)	4/05/2018
NSA_V_BDL01_40	Bairnsdale Unit 1 >= 40 MW for Network Support Agreement	5 (0.41)	21/08/2013
NSA_V_BDL02_40	Bairnsdale Unit 2 >= 40 MW for Network Support Agreement	4 (0.33)	21/08/2013
F_T+COGT_TL_L6	Out = one Comalco to George Town line, Tasmania Lower 6 sec requirement for the loss of the remaining Comalco to George Town line, Basslink unable to transfer FCAS	3 (0.25)	12/04/2016
T_T_FASH_2_N-2	Out = Nil, loss of both Farrell to Sheffield lines declared credible, Farrell 220 kV bus split, West Coast 220/110 kV parallel open, limit Mackintosh >= 90% of West Coast load	3 (0.25)	16/02/2018
Q_NIL_STRGTH_SMSF	Out = Nil, limit Sun Metal SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	2 (0.16)	5/08/2020
V_BANSF_22INV	Limit Bannerton Solar Farm upper limit to 0 MW if number of inverter available exceed 22. Constraint swamp out if number of inverter available not exceed 22. This is to manage voltage oscillation. DS only	2 (0.16)	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
N_BKHSF_40INV	Constraint equation violated for 14 non-consecutive DIs, 13 of which were consecutive with violation degree of 0.01 MW occurring on 24/08/2020.Constraint equation violated due to Broken Hill Solar Farm exceeding inverter limit.
V_MURRAWRWF_30WT	Constraint equation violated for 11 non-consecutive DIs,4 of which were consecutive with violation degree of 0.01 MW. Constraint equation violated due to Murra Warra Wind Farm exceeding turbine limit.
DSNAP_V::S_NIL_MAXG1	Constraint equation violated for 8 non-consecutive DIs where max violation of 2094.93 occurred on 02/08/2020 at 1330 Hrs. Constraint equation violated due to issue with scaling factor for South Australia PV calculation. Constraint equation was initially blocked and now removed. The DATASNAP set contents has been reviewed and the RHS logic for the active constraints changed to avoid this issue in the future.
F_T_AUFLS2_R6	Constraint equation violated for 7 non-consecutive DIs,3 of which were consecutive where max violation of 18.12 MW occurred on 30/08/2020 at 1215hrs. Constraint equation violation occurred due to Tasmania raise 6-seconds service availability being less than the requirement.
NSA_V_BDL01_40	Constraint equation violated for 5 DIs with max violation of 40 MW. Constraint equation violation occurred due to Bairnsdale unit 1 being limited by its start-up profile.
NSA_V_BDL02_40	Constraint equation violated for 4 DIs with max violation of 40 MW occurring at 1910 and 1915 hrs. Constraint equation violation occurred due to Bairnsdale unit 2 being limited by its start-up profile.
F_T+COGT_TL_L6	Constraint equation violated for 3 DIs on 04/08/2020 at 0355 hrs, 0440 hrs and 0445 hrs with max violation of 68.18 MW occurring at 0355 hrs. Constraint equation violation occurred due to Tasmania's 6 second lower regulation service availability being less than the requirement.
T_T_FASH_2_N-2	Constraint equation violated for 3 DIs on 15/08/2020 and 27/08/2020 at 0055hrs,1855hrs and 1900hrs with max violation of 48.11 MW occurring on 15/08/2020 at 0055hrs. Constraint equation violation occurred due to constraint equation being invoked without ramping.
Q_NIL_STRGTH_SMSF	Constraint equation violated for 2 DIs on 23/08/2020 at 1010 hrs and 1015 hrs with max violation of 44.81 MW occurring at 1015 hrs. Constraint equation violated due to Sun Metal Solar Farm non-conforming.
V_BANSF_22INV	Constraint equation violated for 2 DIs on 19/08/2020 at 1650 hrs and 1655 hrs with violation degrees of 0.001 MW. Constraint equation violated due to Bannerton Solar Farm exceeding 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_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	4127 (343.92)	-78.72 (-116.0)
S:V_PA_SVC_420	V-SA Import	Out= one Para SVC, Oscillatory stability limit for SA to VIC on Heywood upper transfer limit of 420 MW	1491	-420.0

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
			(124.25)	(-420.0)
Q^^NIL_QNI_SRAR	NSW1-QLD1 Import	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	1437 (119.75)	-985.32 (-1129.82)
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	1432 (119.33)	-239.65 (-459.0)
N^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	1052 (87.67)	-476.54 (-970.41)
N^^V_NIL_1	V-S-MNSP1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	1032 (86.0)	46.97 (-150.0)
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	919 (76.58)	-303.1 (-459.0)
F_Q++MUTW_L6	NSW1-QLD1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	836 (69.67)	-340.05 (-614.62)
F_Q++MUTW_L6	N-Q-MNSP1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	775 (64.58)	-16.79 (-65.0)
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	763 (63.58)	-345.2 (-459.0)

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 6 – Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_SYDS_4E536CCA	22/08/2020 19:10 to 22/08/2020 19:25	The automated constraint equation was created to avoid overload Waubra to Ballarat 220 kV line on trip of Red Cliffs to Wemen to Kerang 220 kV line under system normal condition.
CA_SYDS_4E536A9C	22/08/2020 19:05 to 22/08/2020 19:25	The constraint automation was an improved version of CA_SYDS_4E536CCA.

Constraint Set ID	Date Time	Description

2.5.1 Further Investigation

CA_SYDS_4E536CCA: Investigated. The existing constraint equation V>>V_NIL_9 has now been updated to manage this scenario.

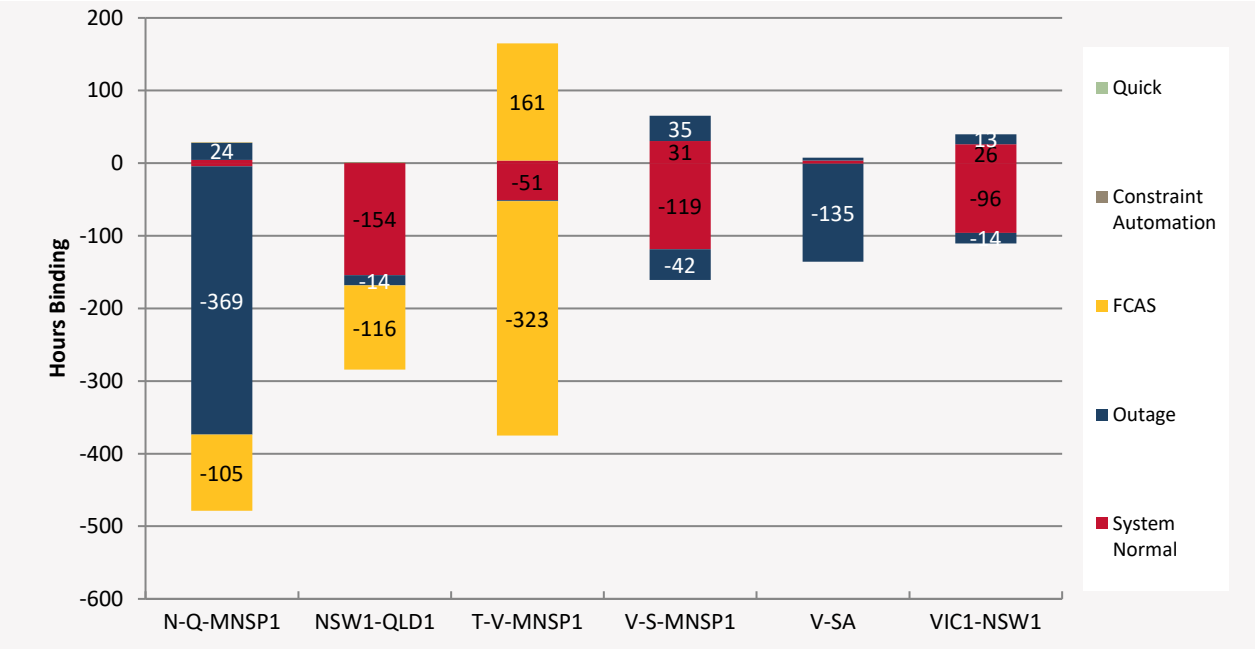
CA_SYDS_4E536A9C: Investigated. Same action has conducted as CA_SYDS_4E536CCA.

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.

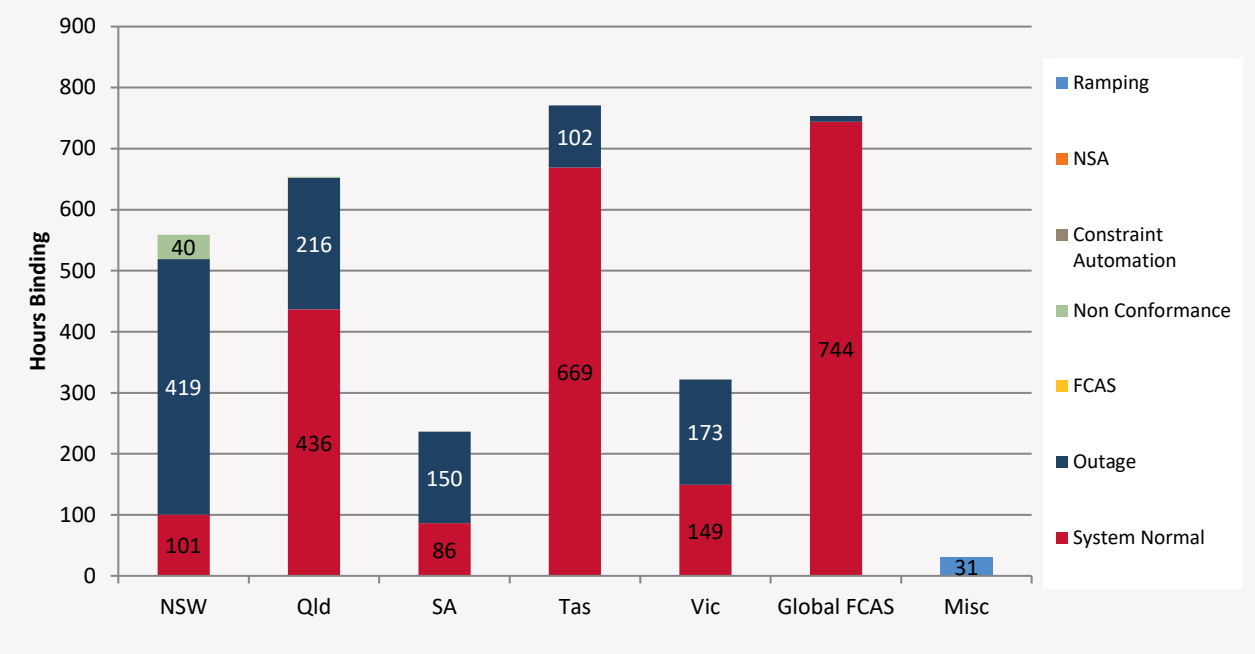
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

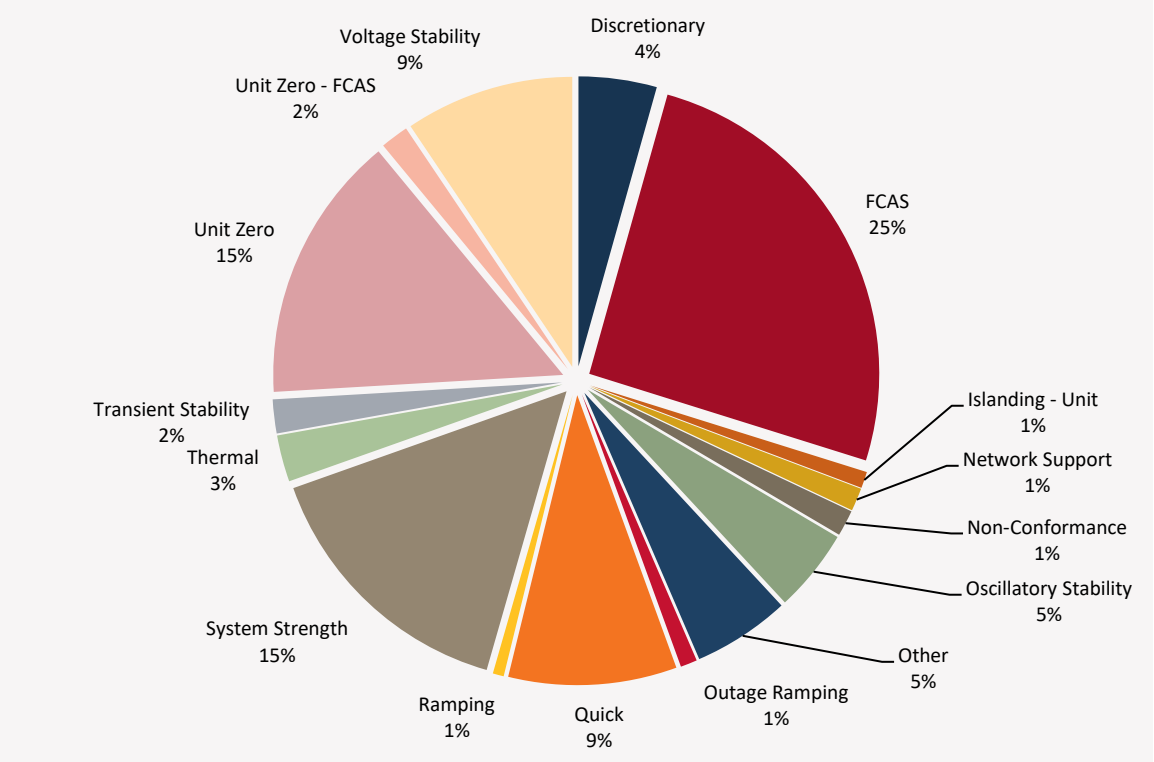
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

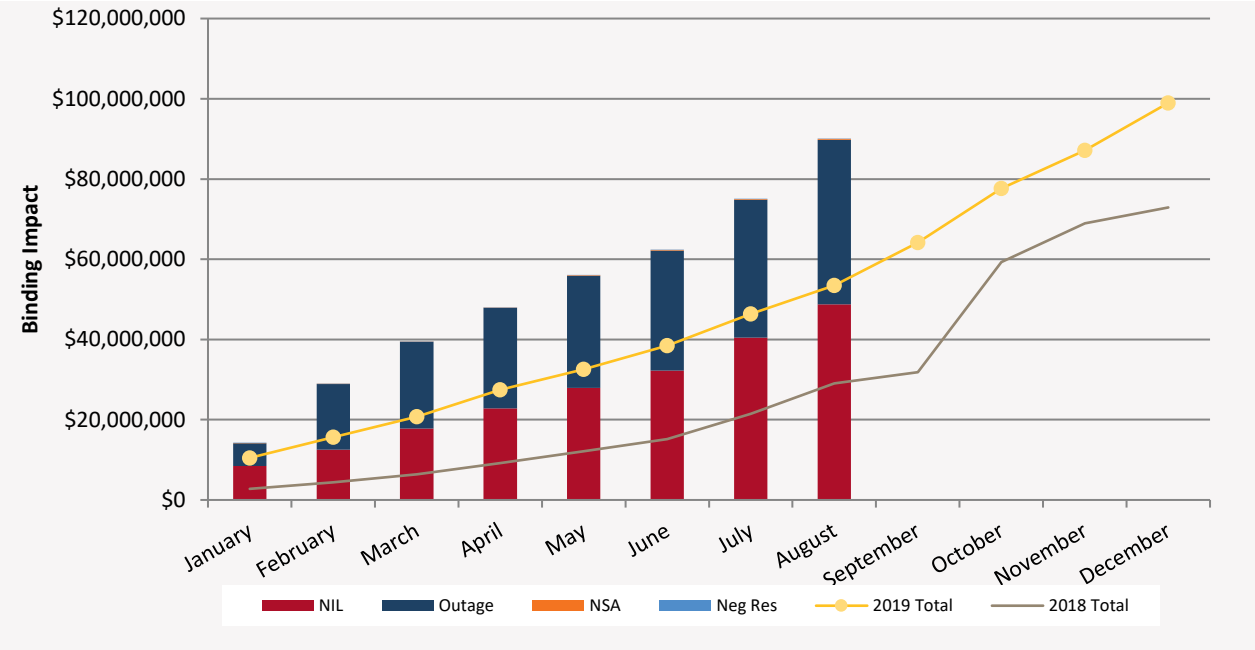
Figure 3 Binding by limit type



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 7 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
Q_NIL_STRGTH_MEWF	Out = Nil, limit Mt Emerald WF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	299	7,200,000 % (144.)	192,698 % (68.62)
Q_NIL_STRGTH_HAUSF	Out = Nil, limit Haughton SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62	387	4,000,000 % (50.)	82,716% (15.37)

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	19	25,013% (141.65)	2,712% (79.74)
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	51	11,773% (120.1)	634% (41.68)
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.	152	875% (9,002)	22.41% (293.62)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	147	408% (355.83)	11.16% (35.63)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	44	343% (22.9)	79.94% (12.5)
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.	149	252% (447.22)	56.94% (193.94)
V::N_X_ARWBBA_V1	Out = Ararat to Waubra to Ballarat 220kV lines (complete circuit O/S), prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	7	203% (215.36)	111.64% (161.1)
V^SML_ARWB_3	Out = Ararat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	10	189% (108.67)	82.43% (54.9)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

Q_NIL_STRGTH_HAUSF: 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.

S_NIL_STRENGTH_1: Investigated. Mismatch was due to differences in generator targets 4 hours in the future compared to targets in dispatch. 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.

N_X_MBTE_3B: Investigated and the mismatch was due to issues with forecasting of the Terranora load. The forecasting of the Terranora load has been improved in November 2018.

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 for August 2020.

Table 8 Generator and transmission changes

Project	Date	Region	Notes
Darlington Point Solar Farm	11 August 2020	NSW1	New Generator
Berrybank switching station	14/08/2020	Victoria	Commissioning of new Berrybank switching station which cuts into the existing Ballarat - Terang 220 kV line. This forms the new Ballarat - Berrybank Switching Station 220 kV line and Terang - Berrybank Switching Station 220 kV line.
Davenport - Mt Gunson South 275 kV Transmission line	24/08/2020	SA	Commissioning of New Mt Gunson South Substation: The following equipment has been commissioned and energised - Mt Gunson South North 275kV Bus, Mt Gunson South - South 275 kV Bus, Davenport - Mt Gunson South 275kV Transmission line and Circuit Breakers (CB8072, CB8073, CB8074).

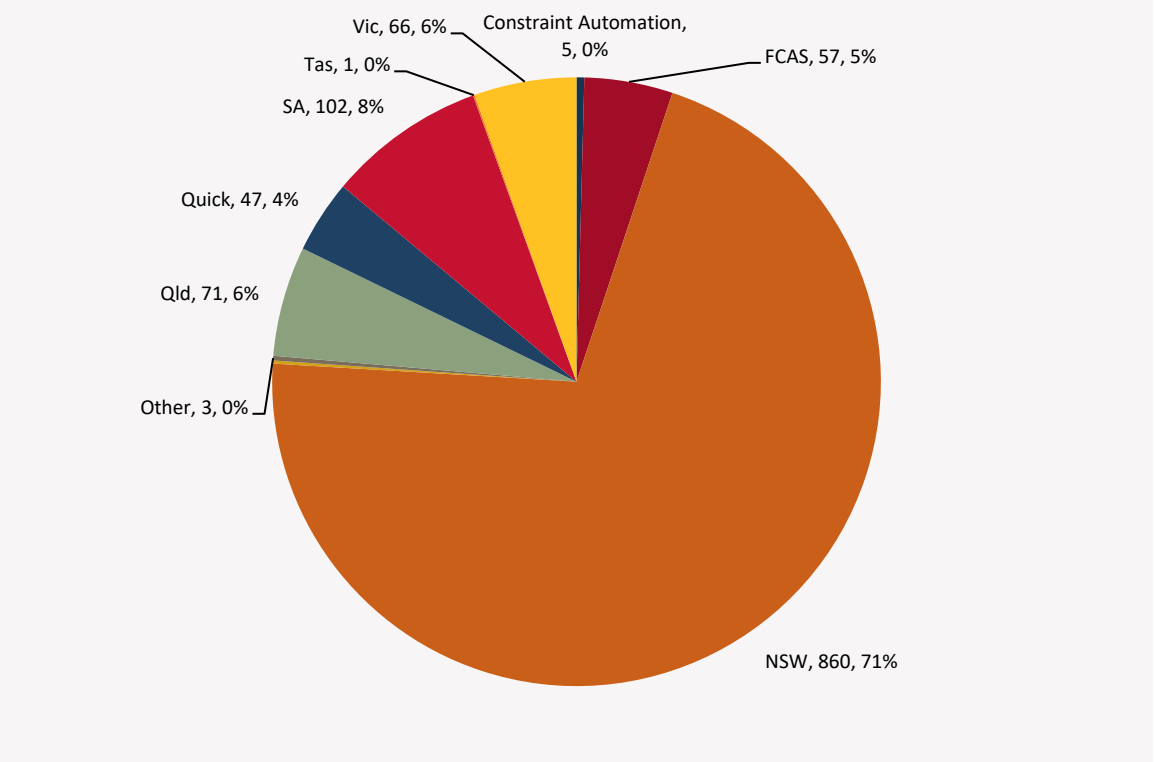
3.1 Constraint Equation Changes

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: http://www.aemo.com.au/Electricity/IT-Systems/NEM

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