AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

July 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 July 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
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 TOA 393	2949 (245.75)	19/06/2020
V_YW_134_580	Upper limits of 580 MW on Yallourn units 1, 3 and 4	2719 (226.58)	3/07/2020
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	2460 (205.0)	11/03/2020
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	2442 (203.5)	8/05/2020
Q_STR_333104_HASF25	Limit Haughton SF to 25 % capacity if Stan>=3+Cal>=3+Glad>=3+ (Stan+Cal+Glad) >=10+Kar>=4. Zero otherwise	2355 (196.25)	22/06/2020
Q_STR_333104_MEWF25	Limit Mt Emerald WF to 25 % capacity if Stan>=3+Cal>=3+Glad>=3+ (Stan+Cal+Glad) >=10+Kar>=4. Zero otherwise	2355 (196.25)	22/06/2020
Q_STR_333104_SMSF25	Limit Sun Metals SF to 25 % capacity if Stan>=3+Cal>=3+Glad>=3+ (Stan+Cal+Glad) >=10+Kar>=4. Zero otherwise	2355 (196.25)	22/06/2020
N^^V_NIL_YW134_N-2	Out = Nil, avoid voltage collapse at Southern NSW for loss of Yallourn units 1, 3 and 4 when declared credible and are the largest contingency	1534 (127.83)	3/07/2020
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	1286	19/06/2020

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
	Gorge generators, Zero if it does not meet minimum generator online. Refer to TOA 393	(107.16)	
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	1266 (105.5)	25/11/2013

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 TOA 393	3,365,788	19/06/2020
Q_STR_333104_MEWF25	Limit Mt Emerald WF to 25 % capacity if Stan>=3+Cal>=3+Glad>=3+ (Stan+Cal+Glad) >=10+Kar>=4. Zero otherwise	2,242,763	22/06/2020
Q_STR_333104_HASF25	Limit Haughton SF to 25 % capacity if Stan>=3+Cal>=3+Glad>=3+ (Stan+Cal+Glad) >=10+Kar>=4. Zero otherwise	975,083	22/06/2020
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.	796,000	20/07/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	588,463	29/05/2020
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 TOA 393	427,898	19/06/2020
Q_NIL_STRGTH_KIDSF	Out = Nil, limit Kidston SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron	398,737	31/07/2020

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
	Gorge generators, Zero if it does not meet minimum generator online. Refer to Table 7 of SO_OG_NEM_62		
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.	379,206	16/08/2019
Q>NIL_EMBW_EMLV_DS	Out= Nil, limit Emerald SF to 40MW to avoid overload on Emerald - Lilyvale 66kV line on trip of Emerald - Comet - Blackwater 66kV line (6056 or 6011), swamp if Emerald CBs S612,S610 and Blackwater CB S605 are closed (DS only)	332,891	15/04/2020
Q_NIL_STRGTH_CLRSF	Out = Nil, limit Clare 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	292,816	31/07/2020

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^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	24 (2.0)	8/05/2020
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	5 (0.41)	15/07/2020
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	3 (0.25)	21/12/2018
V_YW_134_580	Upper limits of 580 MW on Yallourn units 1, 3 and 4	3 (0.25)	3/07/2020
F_T++NIL_MG_RECL_R5	Out = Nil, Raise 5 min requirement for a Tasmania Reclassified Woolnorth Generation Event, Basslink able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	3 (0.25)	2/12/2016
F_T++NIL_MG_R5	Out = Nil, Raise 5 min requirement for a Tasmania Generation Event, Basslink able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	2 (0.16)	12/04/2016
V_BANSF_20INV	Limit Bannerton Solar Farm upper limit to 0 MW if number of inverter available exceed 20. Constraint swamp out otherwise. DS only	2 (0.16)	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	2 (0.16)	13/07/2020
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	1 (0.08)	30/04/2018

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
T_GO_250	Discretionary 250 MW upper limit on total Gordon generation	1 (0.08)	21/08/2013

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
N^N-LS_SVC	Constraint equation violated for non-consecutive 24 DIs, 16 of which were consecutive. Max violation of 47.99 MW occurred on 09/07/2020 at 0920 hrs. Constraint equation violation occurred due to competing requirements set by the import constraints, N_X_MBTE_3B and N_X_MBTE2_B
NRM_QLD1_NSW1	Constraint equation violated for 5 DIs with max violation of 77.42 MW occurred on 14/07/2020 at 0725 hrs. Constraint equation violation occurred due to competing requirements set by the export constraints, N^^Q_MUTW_1_B1, N^N-LS_SVC and F_Q++MUTW_R6.
NSA_V_NPSD_100	Constraint equation violated for 3 DIs on 13/07/2020 at 0145 hrs to 0155 hrs. Max violation of 40.94 MW occurred on 0145 hrs. Constraint equation violation occurred due to Newport PS being limited by its start-up profile.
V_YW_134_580	Constraint equation violated for 3 DIs on 03/07/2020 at 1905 hrs to 1915 hrs. Max violation of 36.61 MW occurred at 1905 hrs. Constraint equation violation due to Yallourn unit 3 and 4 non-conforming.
F_T++NIL_MG_RECL_R5	Constraint equation violated for 3 DIs on 14/07/2020 at 0905 hrs, 22/07/2020 at 0605 hrs and 23/07/2020 at 0525 hrs. Max violation of 6.9 MW occurred on 14/07/2020. Constraint equation violation occurred due to Tasmania's raise 5-minute service availability was less than the requirement.
F_T++NIL_MG_R5	Constraint equation violated 2 DIs on 14/07/2020 at 0905 hrs and 22/07/2020 at 0605 hrs. Max violation of 5.42 MW occurred on 14/07/2020. Constraint equation violation occurred due to the same reason as F_T++NIL_MG_RECL_R5.
V_BANSF_20INV	Constraint equation violated for 2 DIs on 14/07/2020 at 0705 hrs and 0740 hrs with violation degrees of 0.01 MW. Constraint equation violation occurred due to Bannerton SF exceeding their inverter limits.
V_MURRAWRWF_30WT	Constraint equation violated for 2 DIs on 14/07/2020 at 0705 hrs and 27/07/2020 at 1110 hrs with violation degree of 0.01 MW. Constraint equation violation occurred due to Murra Warra WF exceeding their turbine limits.
F_T_NIL_MINP_R6	Constraint equation violated for 1 DI on 01/07/2020 at 0910 hrs with violation degree of 5.22 MW. Constraint equation violation occurred due to Tasmania's raise 6-second service availability being less than the requirement.
T_GO_250	Constraint equation violated for 1 DI on 29/07/2020 at 1340 hrs with violation degree of 2.1 MW. Constraint equation violation occurred due to Gordon generation non-conforming.

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^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	2458 (204.83)	-314.02 (-811.36)
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	2428 (202.33)	-74.56 (75.51)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	2232 (186.0)	266.63 (446.01)
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	2220 (185.0)	31.62 (-150.0)
F_Q++MUTW_L6	NSW1-QLD1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	1603 (133.58)	-341.96 (-617.07)
F_Q++MUTW_L6	N-Q-MNSP1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	1545 (128.75)	-47.03 (-127.99)
N^^V_NIL_YW134_N-2	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of Yallourn units 1, 3 and 4 when declared credible and are the largest contingency	1532 (127.67)	-225.86 (-588.63)
N^^V_NIL_YW134_N-2	V-S-MNSP1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of Yallourn units 1, 3 and 4 when declared credible and are the largest contingency	1527 (127.25)	19.9 (-171.0)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	1266 (105.5)	-89.61 (-132.0)
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	868 (72.33)	58.71 (-446.0)

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.

Non-real time constraint automation was not used.

2.5.1 Further Investigation

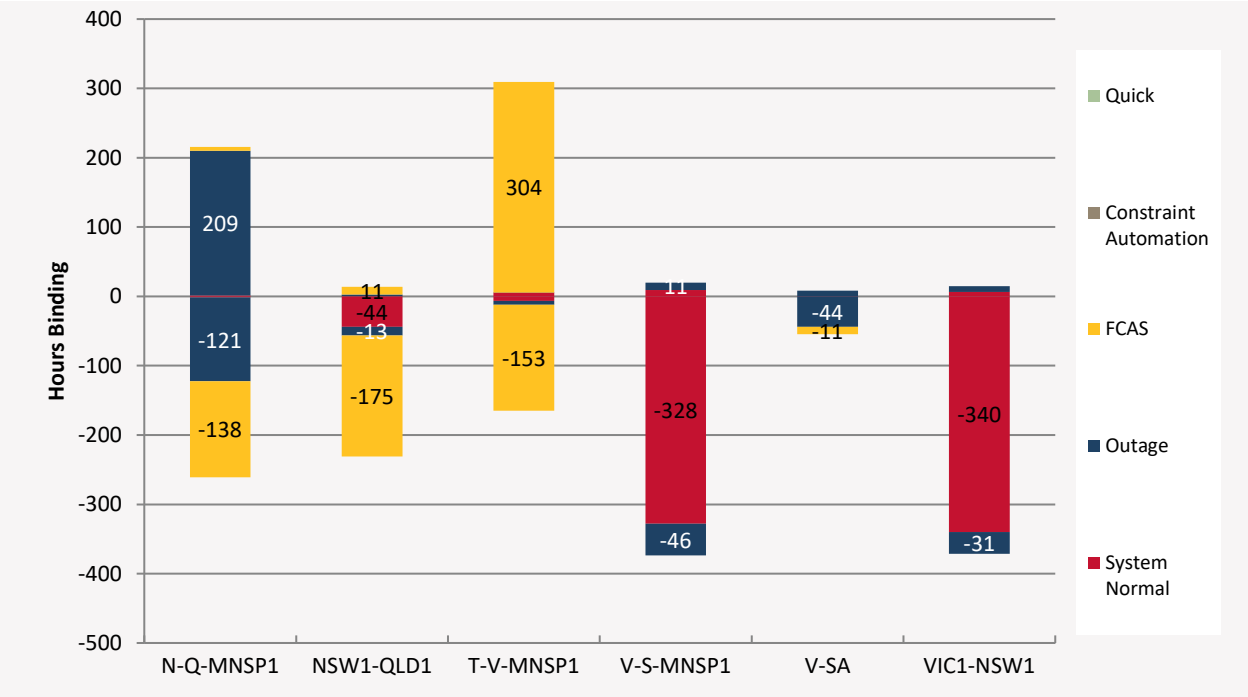
Non-real time constraint automation was not used.

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.

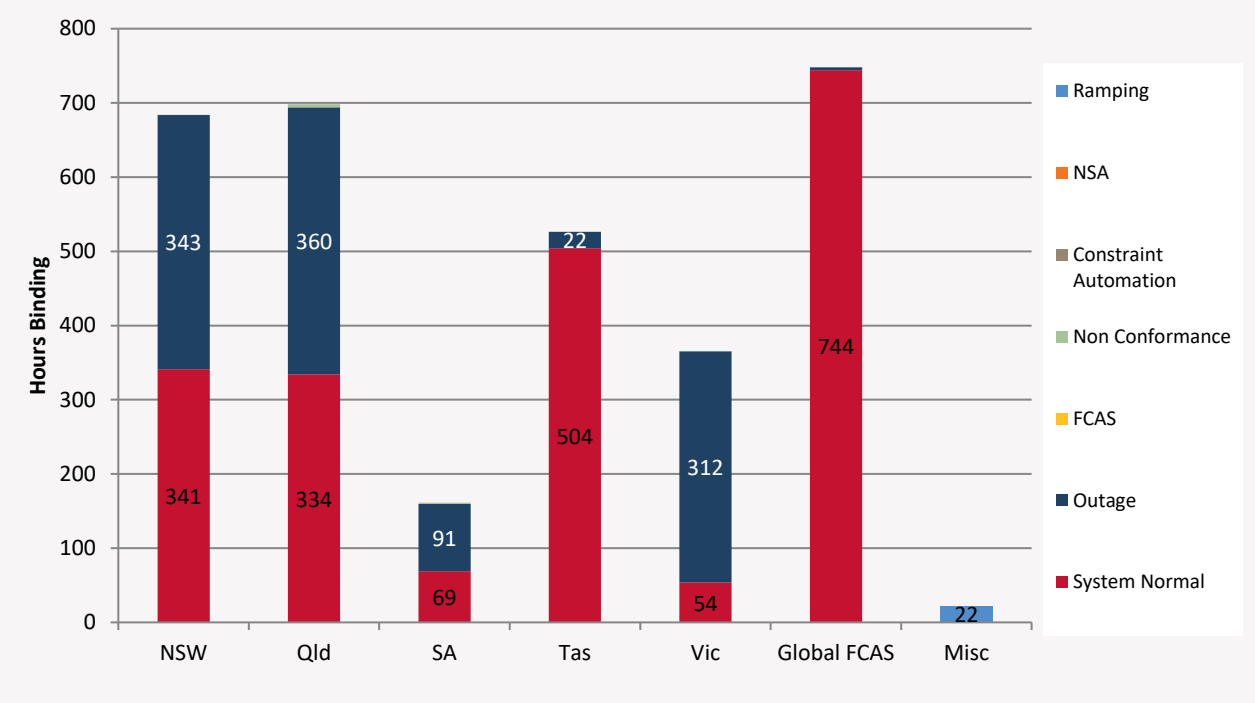
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

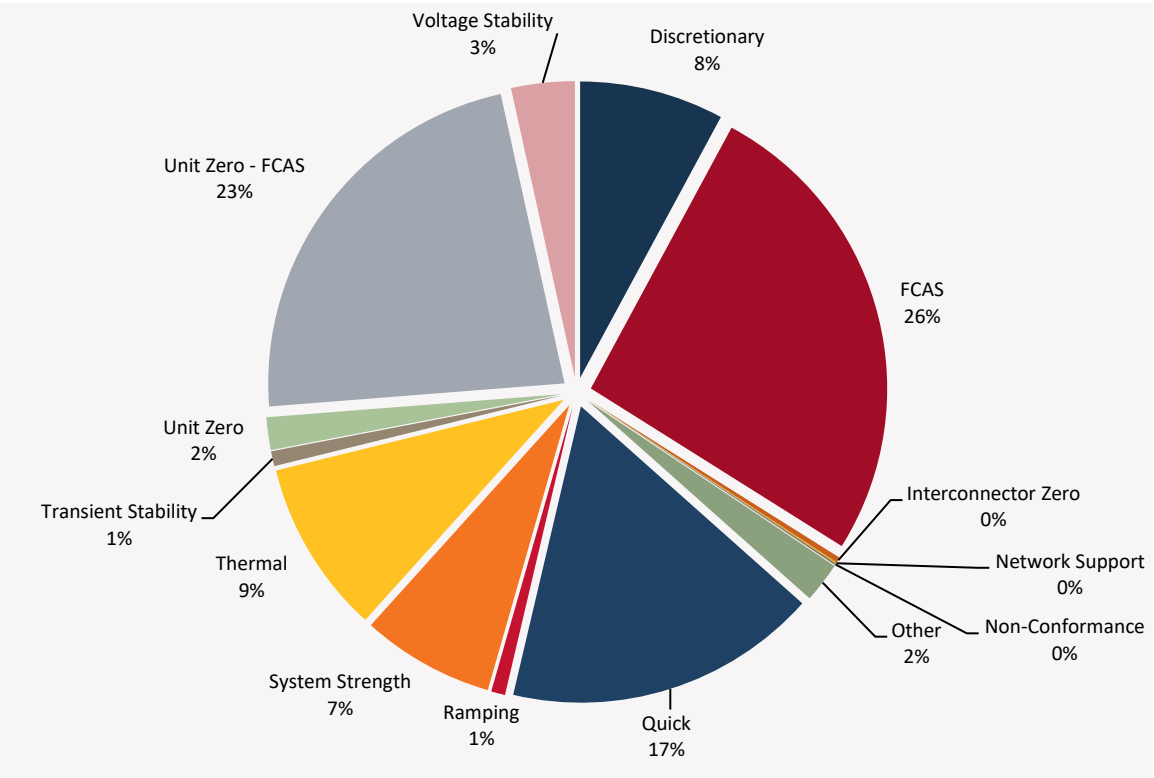
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

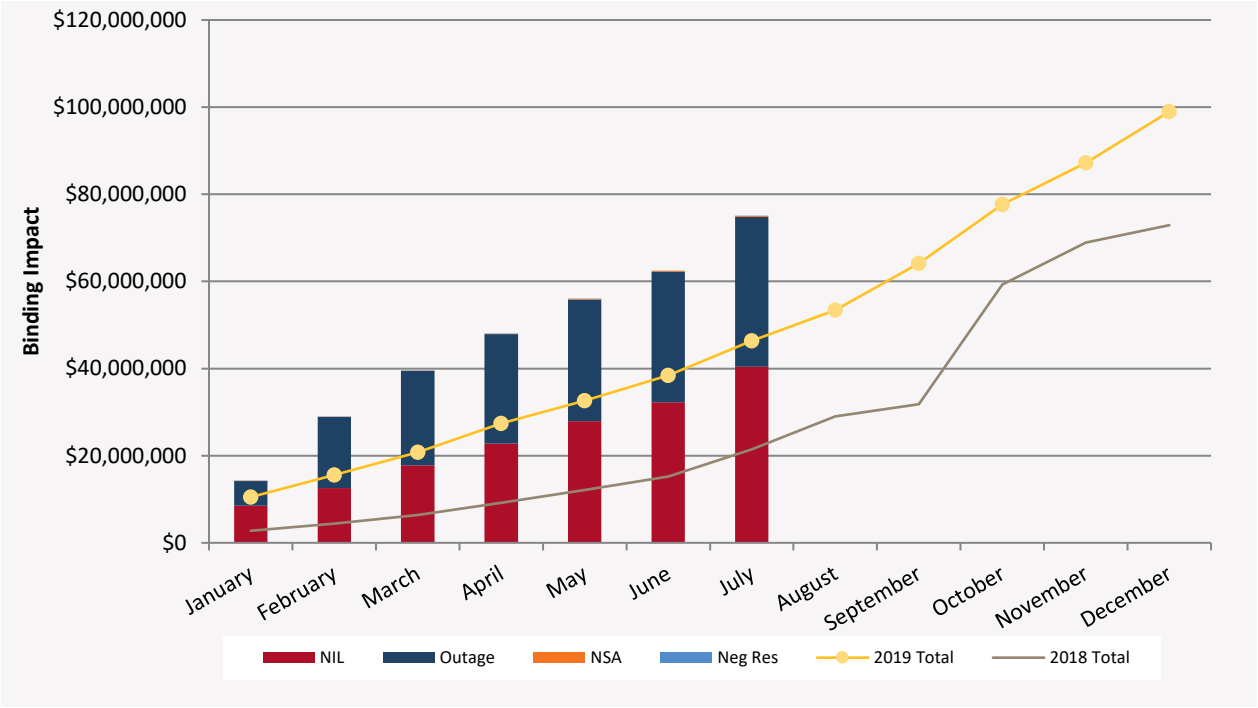
Figure 3 Binding by limit type



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
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	465	18,823% (114.69)	374% (37.56)
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.	132	864% (9,035)	13.15% (260.27)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
S>>V_CGTI_PPPG_TIPA	Out= Cherry Gardens - Torrens Island 275kV line, avoid O/L Torrens Island - Para 275kV line on trip of Pelican Point - Parafield Gardens West 275kV line, Feedback	3	776% (266.72)	446% (260.7)
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.	13	576% (143.05)	235% (76.99)
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	5	233% (91.5)	120.15% (56.75)
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.	223	209% (417.5)	60.35% (195.85)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	693	194% (447.24)	32.54% (128.7)
V_VS_LB_CAN_50	Limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement when SA is at risk of separation.	4	189% (20.01)	129.6% (14.38)
N^^V_CNCW_1	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W), avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	39	137.48% (155.05)	52.73% (86.66)
N^^V_DDSM1	Out = Dederang to South Morang 330 kV line, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink or the parallel Dederang to South Morang 330kV line	17	126.19% (150.78)	49.65% (82.84)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N^N-LS_SVC: Investigated and constraint equation was updated on 27/08 to improve PD performance.

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.

S>>V_CGTI_PPPG_TIPA: 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.

N^^V_NIL_1: The Pre-dispatch formulation for this constraint equation was recalculated in February 2020 (with an update to the limit advice). Pre-dispatch formulation were improved in March 2020. No further improvements can be made at this stage

N^^V_CNCW_1: 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.

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 July 2020.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Davenport R5 275 kV reactor	6 July 2020	SA	Commissioning of a new 50MVar 275kV bus reactor at Davenport substation. Currently connected to the 275 kV Davenport No.1 and No.2 bus tie. It will be connected to the future Davenport - Mt Gunson South 275 kV line.
Wurdong – Teebar Creek 275 kV line	17 July 2020	QLD	H40 Wurdong – H63 Teebar Creek No.819 275 kV line has been commissioned. H40 Wurdong – H6 Gin Gin No. 819 275 kV line and the H6 Gin Gin – H63 Teebar Creek No. 826 275 kV line have been decommissioned.

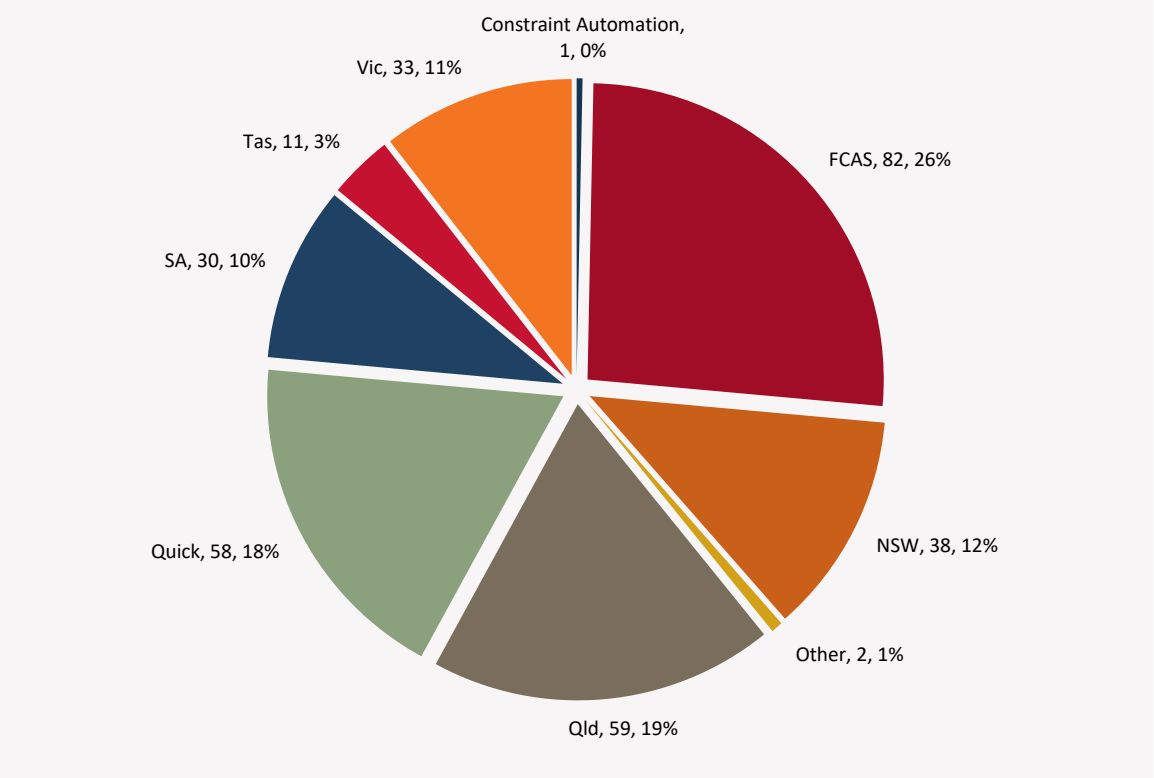
3.1 Constraint Equation Changes

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