Monthly Constraint Report

September 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 September 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
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	6645 (553.75)	21/08/2013
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	5272 (439.33)	11/09/2020
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	3107 (258.91)	11/09/2020
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.	1869 (155.75)	26/03/2020
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)	1581 (131.75)	1/01/2020
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.	1426 (118.83)	19/08/2020
S:V_PA_SVC_420	Out= one Para SVC, Oscillatory stability limit for SA to VIC on Heywood upper transfer limit of 420 MW	1416 (118.0)	7/08/2018
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1139	17/09/2020

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
		(94.91)	
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.	985 (82.08)	16/08/2019
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	963 (80.25)	11/09/2020

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	5,112,651	11/09/2020
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	3,006,430	11/09/2020
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.	1,400,790	19/08/2020
V_MURRAWRWF_FLT_90	Limit Murra Warra Wind Farm upper limit to 90 MW to manage system stability on the next contingency due to voltage oscillation	932,268	2/09/2019
N_DARLSF1_ZERO	Darlington Point solar farm upper limit of 0 MW and all inverters disconnected.	918,728	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_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.	909,294	16/08/2019
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)	486,926	1/01/2020
N_BROKENHSF_FLT_26	Limit Broken Hill Solar Farm upper limit to 26 MW to manage post contingent voltage oscillation	261,134	5/09/2019
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	171,855	21/08/2013
V>>V_NIL_9	Out= Nil, avoid O/L Waubra to Ballarat 220kV line on trip of Kerang to Bendigo 220kV line, Feedback	143,391	1/06/2020

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

Table 1 – Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
Q_STR_311393_HASF	Limit Haughton SF to 20% of Max capacity if Stan>=3+CalB>=1+CalC>=1+Glad>=3+Kar>=3+(Stan+Cal+Glad)>=9,NQLD>450&470(AVG),Ross_FN>250&270(AVG), Zero otherwise	93 (7.75)	14/09/2020
V_KARSF_19INV	Limit Karadoc Solar Farm upper limit to 0 MW if number of inverter available exceed 19. Constraint swamp out otherwise. DS only	15 (1.25)	13/07/2020
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	7 (0.58)	13/07/2020
V_WEMENSF_19INV	Limit Wemen Solar Farm upper limit to 0 MW if number of inverter available exceed 19. Constraint swamp out otherwise. DS only	7 (0.58)	13/07/2020
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	6 (0.5)	13/07/2020
F_Q++MUTW_R6	Out = Muswellbrook to Tamworth (88) line, Qld Raise 6 sec Requirement	4 (0.33)	10/09/2019
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	4 (0.33)	21/12/2018
F_Q++MUTW_R60	Out = Muswellbrook to Tamworth (88) line, Qld Raise 60 sec Requirement	4 (0.33)	10/09/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
S_WATERLWF_RB	Out= Nil, Limit Waterloo WF output to its runback MW capability, DS only	3 (0.25)	22/06/2017

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
Q_STR_311393_HASF	Constraint equation violated for 93 consecutive DIs on 08/09/2020 from 0705 hrs to 1445 hrs with max violation of 0.002 MW occurring for 60 consecutive intervals from 0945 hrs to 1445 hrs. Constraint equation violated due to Haughton Solar Farm exceeding inverter limits.
V_KARSF_19INV	Constraint equation violated for 15 non-consecutive DIs on 16/07/2020 and 17/09/2020 for 3 consecutive intervals ranging from 1645 hrs to 1705 hrs and 1815 hrs to 1835 hrs on 16/09/2020 and 0635 hrs to 0655 hrs on 17/09/2020 with violation degree of 0.01 MW. Constraint equation violation occurred due to Karadoc solar farm exceeding their inverter limit.
N_BKHSF_40INV	Constraint equation violated for 14 non-consecutive DIs, 12 of which were consecutive with violation degree of 0.01 MW occurring on 16/09/2020. Constraint equation violated due to Broken Hill Solar Farm exceeding their inverter limit.
V_MURRAWRWF_30WT	Constraint equation violated for 7 non-consecutive DIs with violation degree of 0.01 MW on 16/09/2020 and 18/09/2020. Constraint equation violated due to Murra Warra Wind Farm exceeding their turbines limit.
V_WEMENSF_19INV	Constraint equation violated for 7 consecutive DIs with violation degree of 0.01 MW on 16/09/2020 from 1645 hrs to 1715 hrs. Constraint equation violated due to Wemen Solar Farm exceeding their inverter limit.
V_BANSF_20INV	Constraint equation violated for 6 consecutive DIs with violation degree of 0.01 MW on 16/09/2020 from 1645 hrs to 1710 hrs. Constraint equation violation occurred due to Bannerton solar farm exceeding their inverter limit.
F_Q++MUTW_R6	Constraint equation violated for 4 DIs with max violation of 97.37 MW occurring on 22/09/2020 at 1900 hrs. Constraint equation violation occurred due to Queensland raise 6-second service availability being less than the requirement.
NSA_V_NPSD_100	Constraint equation violated for 4 DIs with max violation of 68.88 MW on 13/09/2020 at 0205 hrs. Constraint equation violation occurred due to Newport PS being limited by its start-up profile.
F_Q++MUTW_R60	Constraint equation violated for 4 DIs with max violation of 48.37 MW occurring on 22/09/2020 at 1900 hrs. Constraint equation violation occurred due to the same reason as F_Q++MUTW_R6.
S_WATERLWF_RB	Constraint equation violated for 3 DIs with violation degree of 30 MW occurring on 30/09/2020 at 1320 hrs,1325 hrs and 1330 hrs. Constraint equation violation occurred due to Waterloo Wind Farm 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)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	6354 (529.5)	0.0 (0.0)
F_Q++MUTW_L6	NSW1-QLD1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	3555 (296.25)	-242.68 (-565.81)
F_Q++MUTW_L6	N-Q-MNSP1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	3452 (287.67)	-31.71 (-117.37)
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	1848 (154.0)	-89.86 (-459.01)
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	1415 (117.92)	-420.0 (-420.0)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1376 (114.67)	131.53 (459.0)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	1130 (94.17)	687.81 (1209.31)
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	937 (78.08)	-213.78 (-459.0)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	691 (57.58)	106.6 (459.0)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	659 (54.92)	-11.0 (220.0)

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_4E687B6C	07/09/2020 18:35 to 07/09/2020 19:40	The automated constraint equation was created to manage overloading of the Ballarat to Waubra 220 kV line on trip of the Kerang to Wemen to Red Cliffs Kerang 220 kV line under system normal condition
CA_SYDS_4E6886CC	07/09/2020 19:25 to 07/09/2020 19:45	The constraint automation was an improved version of CA_SYDS_4E687B6C.

2.5.1 Further Investigation

CA_SYDS_4E687B6C: Investigated. A new constraint equation V>>V_NIL_7 has been created to manage this scenario.

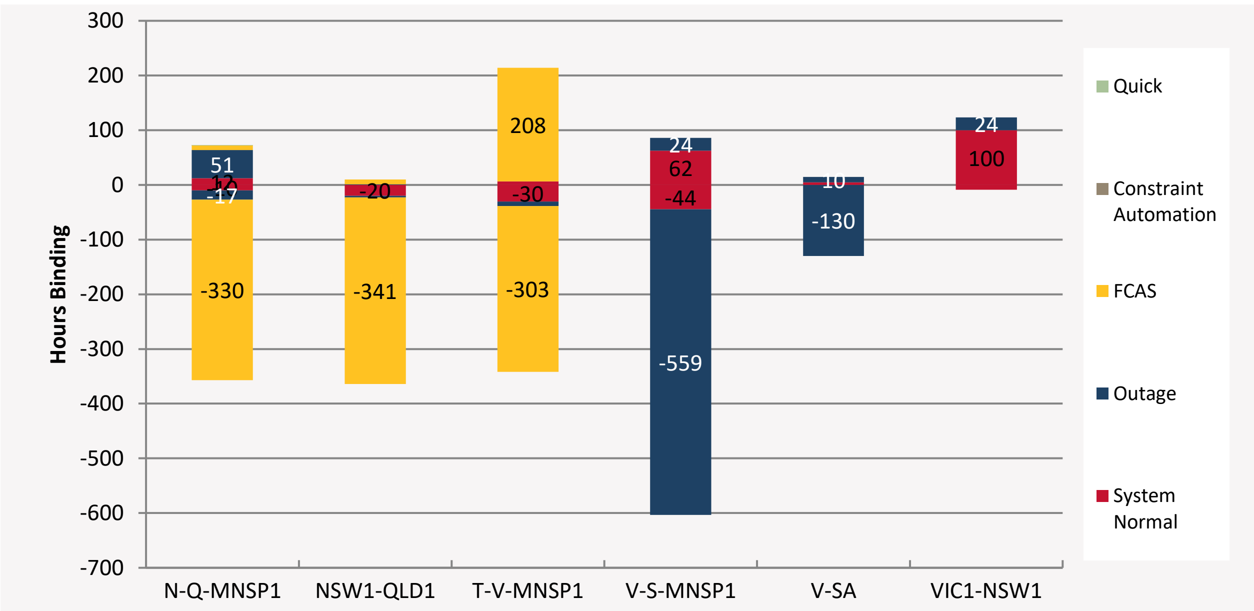
CA_SYDS_4E6886CC: Investigated. Same action has conducted as CA_SYDS_4E687B6C.

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.

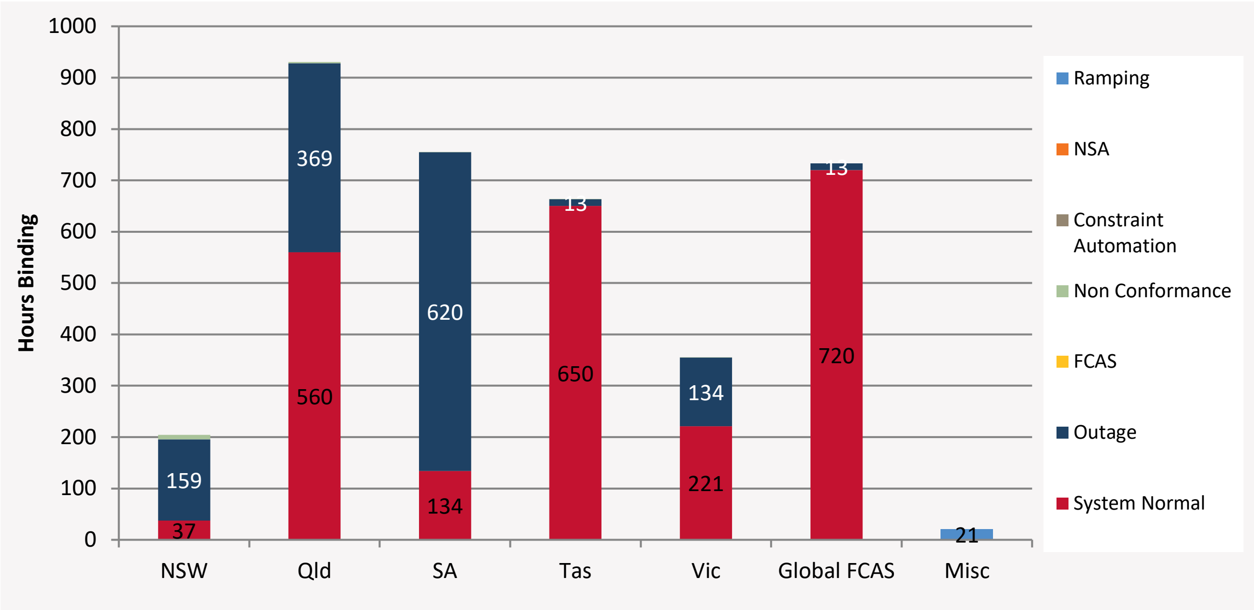
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

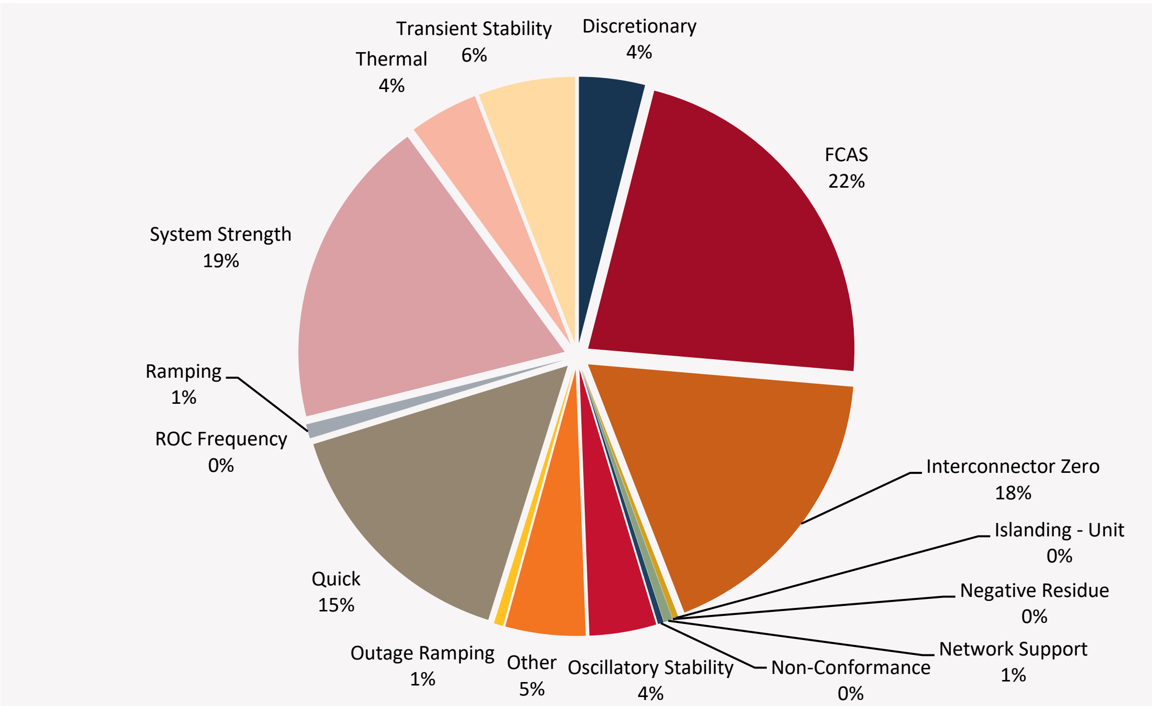
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

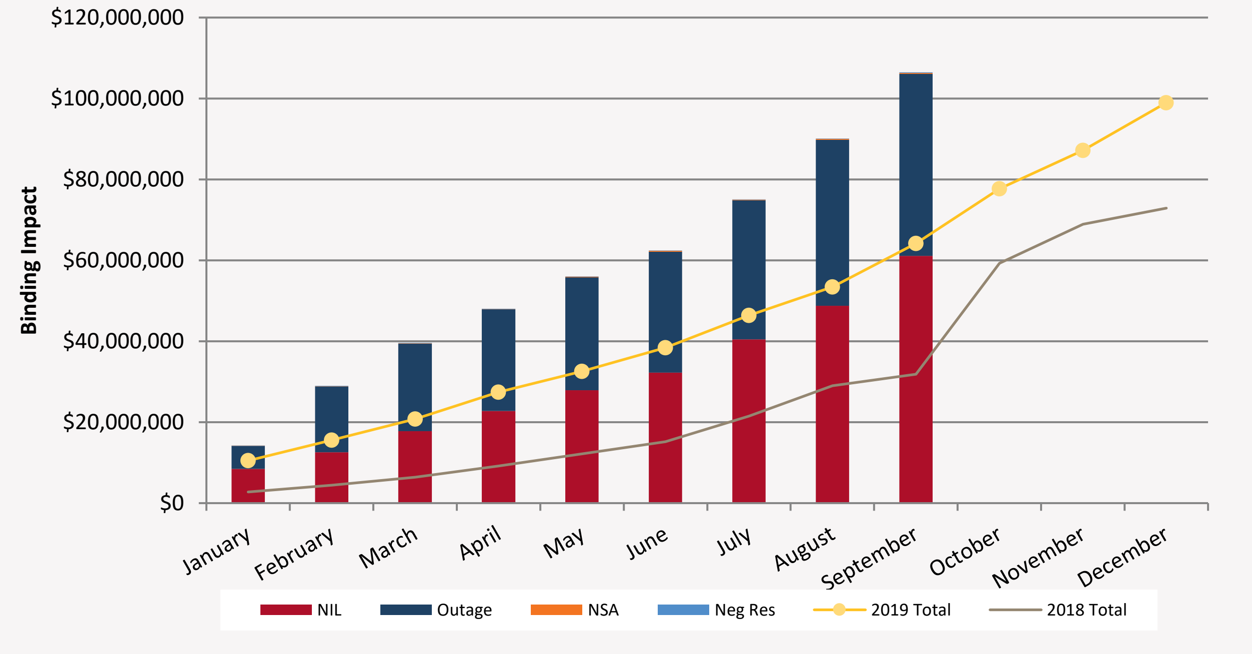
Figure 3 Binding by limit type



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
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	84	12,203% (95.94)	453% (33.02)
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.	274	842% (9,464)	13.15% (204.11)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	22	754% (264.7)	72.34% (53.52)
V::N_MLTX_V1	Out = Moorabool Transformer 500/200kV, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 220 kV.	69	354% (357.36)	47.62% (106.62)
Q_STR_311393_HASF	Limit Haughton SF to 20% of Max capacity if Stan>=3+CalB>=1+CalC>=1+Glad>=3+Kar>=3+(Stan+Cal+Glad)>=9,NQLD>450&470(AVG),Ross_FN>250&270(AVG), Zero otherwise	15	300% (20.)	180% (12.)
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.	12	233% (287.89)	70.69% (76.94)
V::N_MLTX_V2	Out = Moorabool Transformer 500/200kV, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	64	214% (339.79)	52.68% (113.98)
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.	514	181% (362.6)	34.14% (109.96)
V::N_SMSC_V2	Out = one South Morang series capacitor, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	4	153% (289.99)	99.16% (199.94)
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	515	100.01% (50.)	34.06% (12.77)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_MLTX_V1: Investigated and no improvement can be made to the constraint equation at this stage.

Q_STR_311393_HASF: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_MLTX_V2: Investigated and no improvement can be made to the constraint equation at this stage.

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.

V::N_HWSM_V1: 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.

Q_NIL_STRGTH_HAUSF: 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 September 2020.

Table 8 Generator and transmission changes

Project	Date	Region	Notes
Kiamal Solar Farm	1 September 2020	VIC1	New Generator
Warwick Solar Farm 1	22 September 2020	QLD1	New Generator
Warwick Solar Farm 2	22 September 2020	QLD1	New Generator
Torrens Island A Unit 2	30 September 2020	SA1	Deregistered Generator
Torrens Island A Unit 4	30 September 2020	SA1	Deregistered Generator

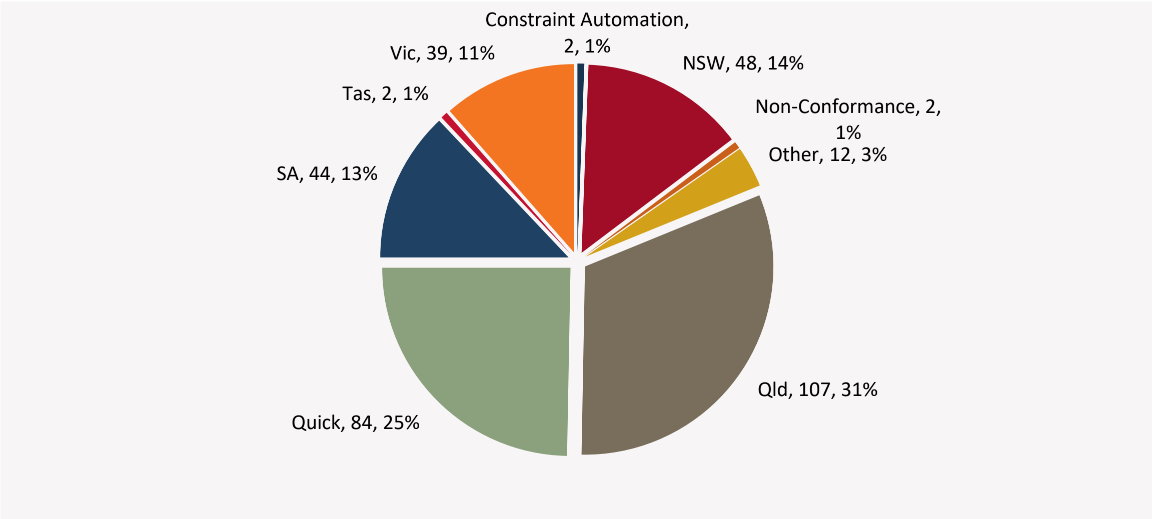
3.1 Constraint Equation Changes

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