AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

January 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 January 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>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	2535 (211.25)	22/01/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	2330 (194.16)	31/01/2020
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	1926 (160.5)	20/01/2020
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)	1095 (91.25)	1/01/2020
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	783 (65.25)	6/11/2019
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.	715 (59.58)	8/01/2020
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	642 (53.5)	20/12/2016
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	622 (51.83)	29/01/2020
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	405	2/10/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
		(33.75)	
V_GANWRSF_FLT_25	Limit Gannawarra solar farm upper limit to 25 MW to manage post contingent voltage oscillation	389 (32.41)	4/09/2019

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
N>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	2,186,036	22/01/2020
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)	803,642	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.	694,487	8/01/2020
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	608,945	20/01/2020
V_MACARTHUR_ZERO	Macarthur upper limit of 0 MW	549,622	21/08/2013
SA_HYSE2	SA / Eastern separation between Heywood and South East (HYTS - SESS), SA to Victoria on VicSA upper limit of 0 MW	487,318	9/01/2014
S-DLBAT-G_0	Discretionary upper limit for Dalrymple Battery (generation component) of 0 MW	441,000	7/08/2018
Q_MEWF1_ZERO	Mt Emerald Wind Farm upper limit of 0 MW	369,745	19/07/2018
F_Q++NIL_R5	Out=Nil, limit Qld to NSW on QNI and Qld Raise 5 min requirement for loss of a NSW 750 MW unit	368,949	2/10/2013
V_GANWRSF_FLT_25	Limit Gannawarra solar farm upper limit to 25 MW to manage post contingent voltage oscillation	330,266	4/09/2019

1 The MCC re-run relaxes any violating constraint equations and constraint equations with a marginal value equal to the constraint equation's violation penalty factor (CVP) x market price cap (MPC). The calculation caps the marginal value in each DI at the MPC value valid on that date. MPC is increased annually on 1st July.

2.3 Top 10 violating constraint equations

A constraint equation is violating when NEMDE is unable to dispatch the entities on the left-hand side (LHS) so the summated LHS value is less than or equal to, or greater than or equal to, the right-hand side (RHS) value (depending on the mathematical operator selected for the constraint equation). The following table includes the FCAS constraint equations. Reasons for the violations are covered in 2.3.1.

Table 3 Top 10 violating constraint equations

Table 1 – Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
F_NQ+MG_R5	Raise 5 min Service Requirement for separated NSW and Qld Generation Event	14 (1.16)	10/09/2019
F_NQ+MG_R60	Raise 60 sec Service Requirement for separated NSW and Qld Generation Event	13 (1.08)	10/09/2019
F_NQ+MG_R6	Raise 6 sec Service Requirement for separated NSW and Qld Generation Event	13 (1.08)	10/09/2019
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	12 (1.0)	21/12/2018
NQ_VST_ISLE_B	Separation between Vic and NSW, allow Vic-NSW to supply Wagga or Northern Victoria	7 (0.58)	9/01/2014
N_URANQ12_ZERO	Uranquinty unit 2 upper limit of 0 MW	7 (0.58)	21/08/2013
N_URANQ14_ZERO	Uranquinty unit 4 upper limit of 0 MW	7 (0.58)	21/08/2013
F_S++MOPS2_R6_1	Raise 6 sec Service Requirement for SA Generation Event, where Mortlake 2 is the largest generation risk in SA (MOPS connects to SA), Segment 1	7 (0.58)	31/01/2020
N_COLEASF1_ZERO	Coleambally solar farm upper limit of 0 MW	6 (0.5)	19/06/2018
N_FINLYSF1_ZERO	Finley solar farm upper limit of 0 MW	6 (0.5)	17/07/2019

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Table 2 – Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
F_NQ+MG_R5	Constraint equation violated for 14 DIs, 13 of which were consecutive. Max violation of 243.97 MW occurred on 04/01/2020 at 1600 hrs. Constraint equation violated due to raise 5-minute service being less than the requirement for New South Wales and Queensland.
F_NQ+MG_R60	Constraint equation violated for 13 non-consecutive DIs. Max violation of 317.62 MW occurred on 04/01/2020 1615 hrs. Constraint equation violated due to raise 60 second service being less than the requirement for New South Wales and Queensland.

Constraint Equation ID (System Normal Bold)	Description
F_NQ+MG_R6	Constraint equation violated for 14 DIs, 13 of which were consecutive. Max violation of 305.62 MW occurred on 04/01/2020 at 1615 hrs. Constraint equation violated due to raise 6 second service being less than the requirement for New South Wales and Queensland.
NSA_V_NPSD_100	Constraint equation violated for 12 non-consecutive DIs with max violation of 85 MW occurring on 11/01/2020 at 0135 hrs. Constraint equation violated due to Newport PS being limited by its start-up profile,
NQ_VST_ISLE_B	Constraint equation violated for 7 non-consecutive DIs with max violation of 459.25 MW occurring on 04/01/2020 at 1615 hrs. Constraint equation violated due to competing requirements with export constraint VN_ZERO.
N_URANQ12_ZERO	Constraint equation violated for 7 consecutive DIs with max violation of 104.12 MW occurring on 04/01/2020 at 1545 hrs. Constraint equation violated due to Uranquinty Unit 2 being limited by its ramp down rate.
N_URANQ14_ZERO	Constraint equation violated for 7 consecutive DIs with max violation of 102.83 MW occurring on 04/01/2020 at 1545 hrs. Constraint equation violated due to Uranquinty Unit 4 being limited by its ramp down rate.
F_S++MOPS2_R6_1	Constraint equation violated for 7 non-consecutive DIs. Max violation of 6.4 MW occurred on 31/01/2020 2130 hrs. Constraint equation violating due to raise 6 second service availability being less than the requirement, as a result of the separation event between South Australia and Victoria.
N_COLEASF1_ZERO	Constraint equation violated for 6 consecutive DIs between 04/01/2020 1545 hrs to 1610 hrs with max violation of 94.08 MW occurring at 1545 hrs. Constraint equation violated due to Coleambally solar farm being limited by its ramp down rate
N_FINLYSF1_ZERO	Constraint equation violated for 6 consecutive DIs between 04/01/2020 1545 hrs to 1610 hrs with max violation of 77.77 MW occurring at 1545 hrs. Constraint equation violated due to Finley solar farm being limited by its ramp down rate.

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)
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	1073 (89.42)	-352.37 (-445.0)
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	1042 (86.83)	-391.66 (-445.01)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	888 (74.0)	143.91 (449.69)
F_MAIN++ML_L6_0400	T-V-MNSP1 Import	Out = Nil, Lower 6 sec requirement for a Mainland Load Event, ML = 400, Basslink able transfer FCAS	850 (70.83)	-344.8 (-445.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N^^V_DDSM1	VIC1-NSW1 Import	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	783 (65.25)	-108.45 (-441.94)
F_MAIN++ML_L6_APD_LD	T-V-MNSP1 Import	Out = Nil, Lower 6 sec requirement for a Mainland Load Event, ML = APD Load excluding Portland WF, Basslink able transfer FCAS	635 (52.92)	-378.29 (-445.0)
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	622 (51.83)	-557.53 (-801.15)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	601 (50.08)	73.43 (445.0)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	578 (48.17)	114.2 (445.0)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	534 (44.5)	-323.41 (-444.97)

2.5 Constraint Automation Usage

The constraint automation is an application in AEMO's energy management system (EMS) which generates thermal overload constraint equations based on the current or planned state of the power system. It is currently used by on-line staff to create thermal overload constraint equations for power system conditions where there were no existing constraint equations or the existing constraint equations did not operate correctly.

The following section details the reason for each invocation of the non-real time constraint automation constraint sets and the results of AEMO's investigation into each case.

Table 3 – Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_BRIS_4D2AA9D0	10/01/2020 16:50 to 10/01/2020 17:00	Unplanned outage of both Eildon to Mount Beauty 220 kV lines and a trip of both Dederang to South Morang 330 kV lines has also occurred. Contingency Analysis indicated over-loading of the Ballarat to Bendigo 220 kV line on trip of both South Morang to Dederang 330kV lines (reclassified as credible due to bushfires) during the unplanned outage of both Mount Beauty to Eildon 220kV lines. RTCA was used to manage overloading on the Ballarat to Bendigo 220 kV line on trip of both South Morang to Dederang 330kV lines.
CA_BRIS_4D2AAD32	10/01/2020 17:05 to 11/01/2020 16:40	The constraint automation was an improved version of CA_BRIS_4D2AA9D0.

2.5.1 Further Investigation

CA_BRIS_4D2AA9D0: This constraint automation constraint set does not require any further investigation. This was utilised for a combination of unplanned outages and a reclassification and does not require any new constraint equations.

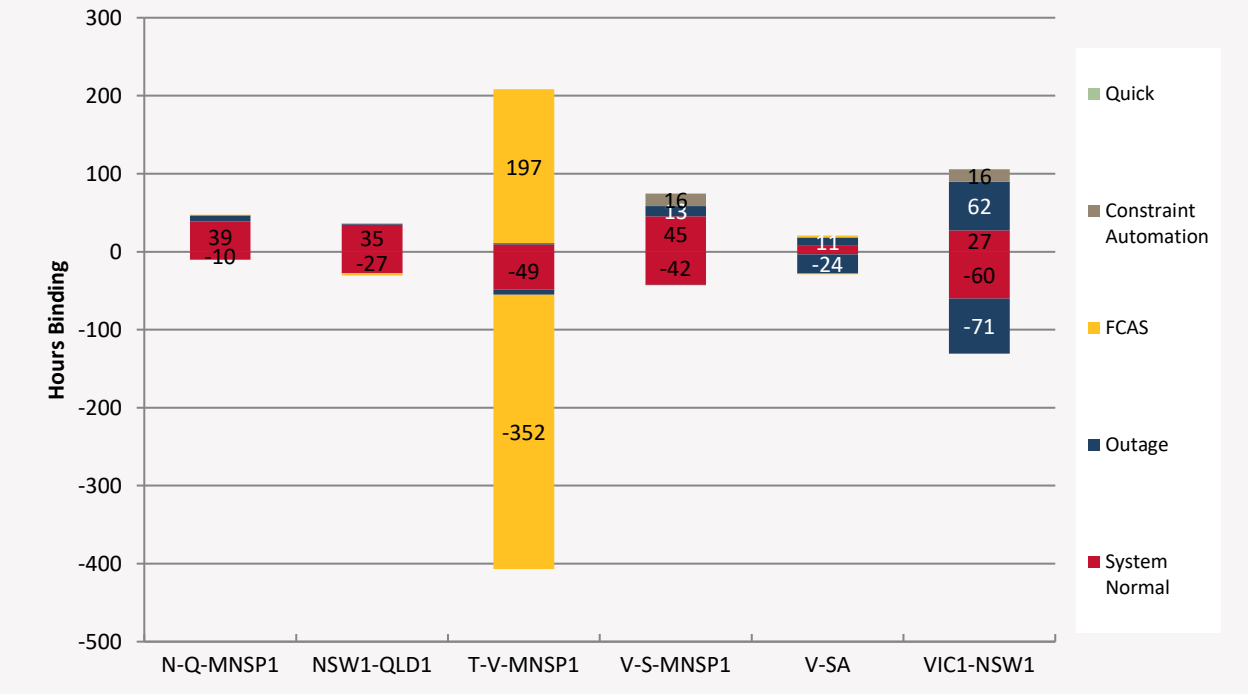
CA_BRIS_4D2AAD32: This constraint automation constraint set does not require any further investigation due to the same reasons as CA_BRIS_4D2AA9D0.

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.

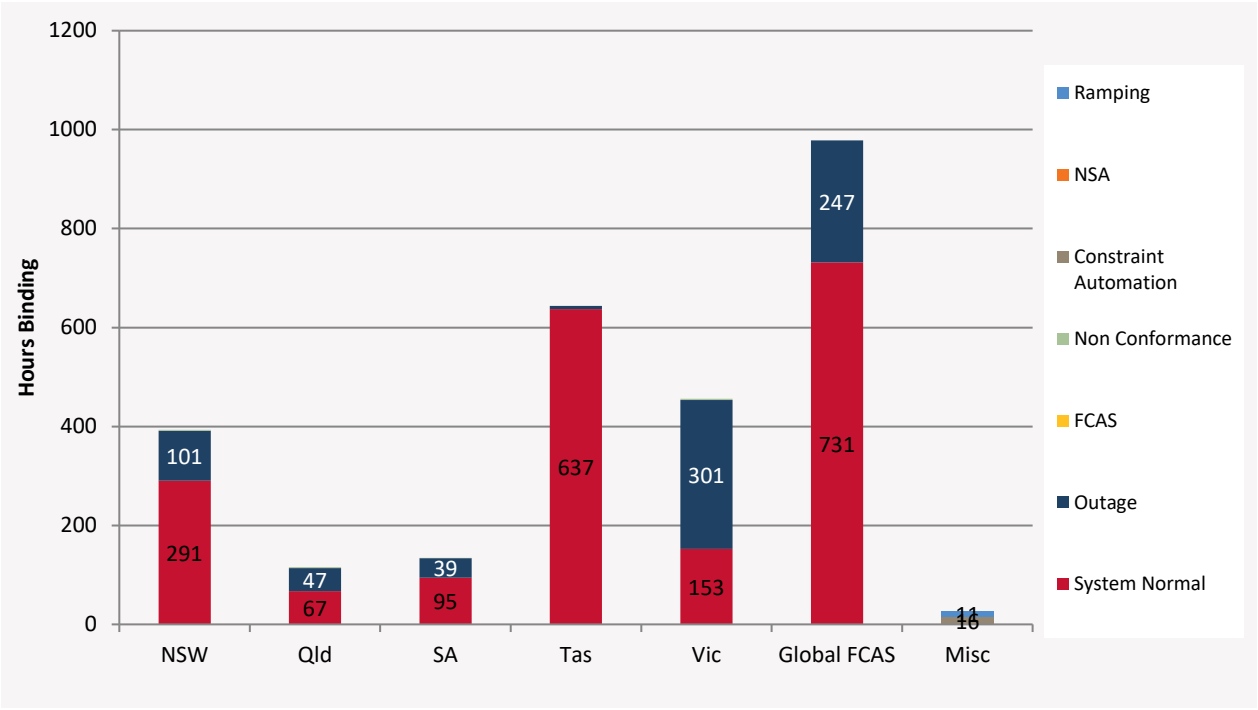
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

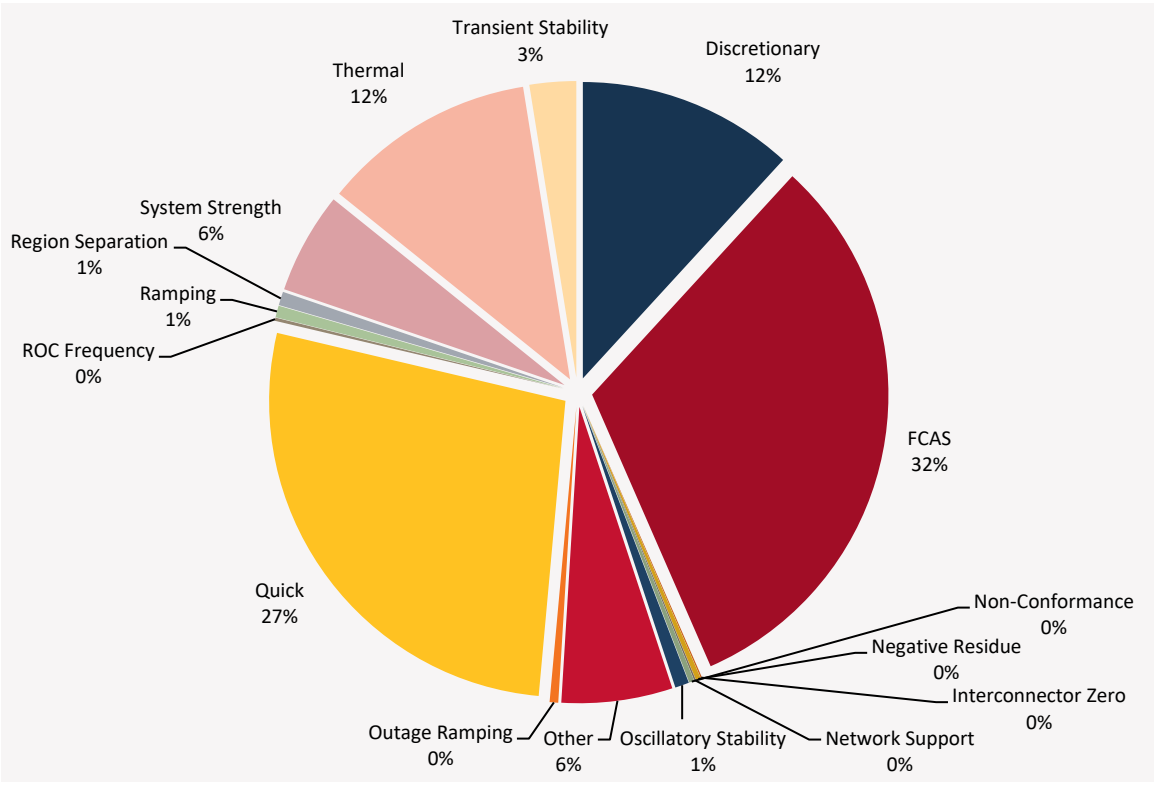
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

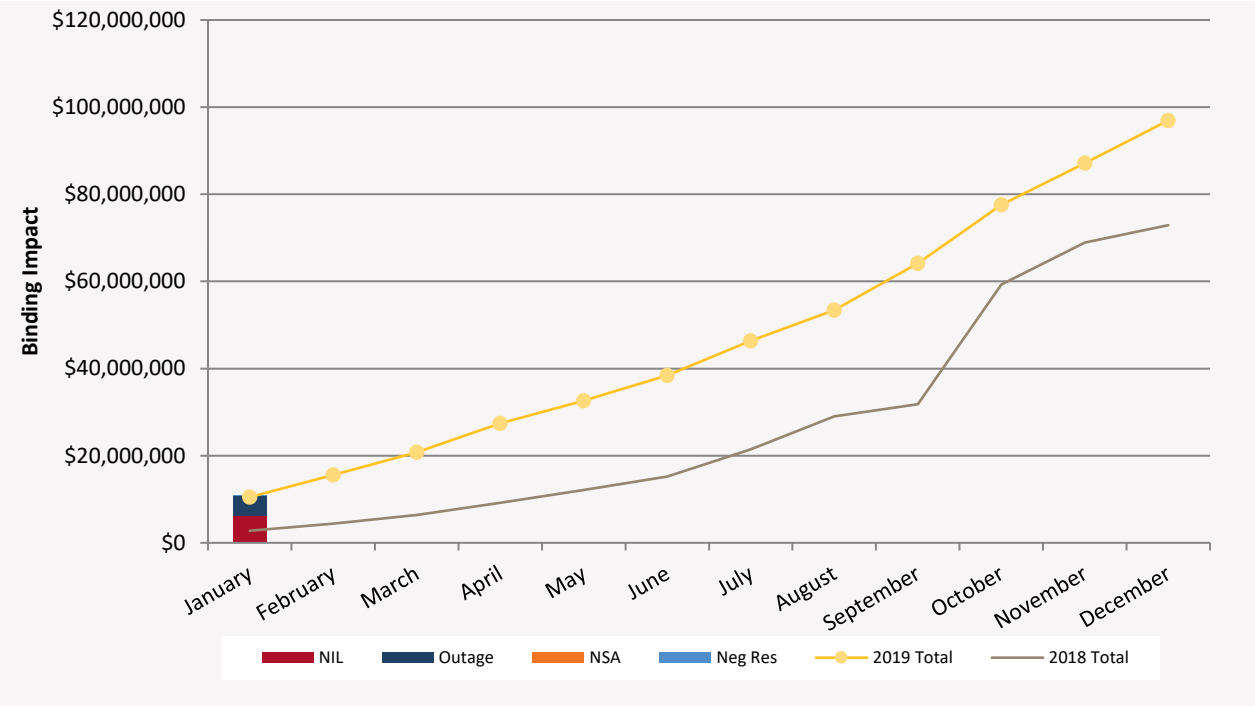
Figure 3 Binding by limit type



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
SA_ISLE_STRENGTH_LB	Maximum limit (0 MW) for Lake Bonney and Canunda Wind Farm for system strength requirements when SA is at risk of separation or when islanded.	11	53,865% (38.44)	9,066% (17.65)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	145	486% (391.41)	48.06% (103.99)

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]	17	280% (138.32)	144.72% (84.61)
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to not exceed 75 MW with Broken Hill solar generating	12	227% (170.)	227% (170.)
V::N_DDSM_V2	Out = Dederang to South Morang 330kV line, prevent transient instability for fault and trip of the parallel Dederang to South Morang 330kV line, VIC accelerates, Yallourn W G1 on 500 kV.	30	216% (110.2)	29.24% (46.88)
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.	5	176% (61.53)	55.49% (40.31)
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	17	105.88% (91.68)	65.76% (57.45)
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	32	100.% (74.)	54.68% (74.)
Q>NIL_MUTE_757	Out= Nil, ECS for managing 757 H4 Mudgeeraba to T174 Terranora 110kV line, Summer and Winter ECS ratings selected by SCADA status.	9	98.33% (99.95)	98.33% (99.95)
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	60	90.07% (45.63)	44.56% (22.99)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

SA_ISLE_STRENGTH_LB: Investigated and 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.

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

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

V::N_DDSM_V2: Investigated and no improvement can be made to the constraint equation at this stage.

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

Q>NIL_MUTE_757: Investigated. Mismatch was due to difference between modelling of Terranora control scheme and line status between DS and PD. No improvement can be made to the constraint equation at this stage.

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.

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 January 2020.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Yarrenlea Solar Farm	7 January 2020	QLD	New Generator
Wild Cattle Hill Wind Farm	7 January 2020	TAS	New Generator
Commissioning of Pieman Substation	24 January 2020	TAS	Piemen 220 kV substation teed into the existing Farrell - Reece No. 1 and No. 2 220 kV lines to form the Farrell - Pieman - Reece No. 1 and No. 2 220 kV lines.

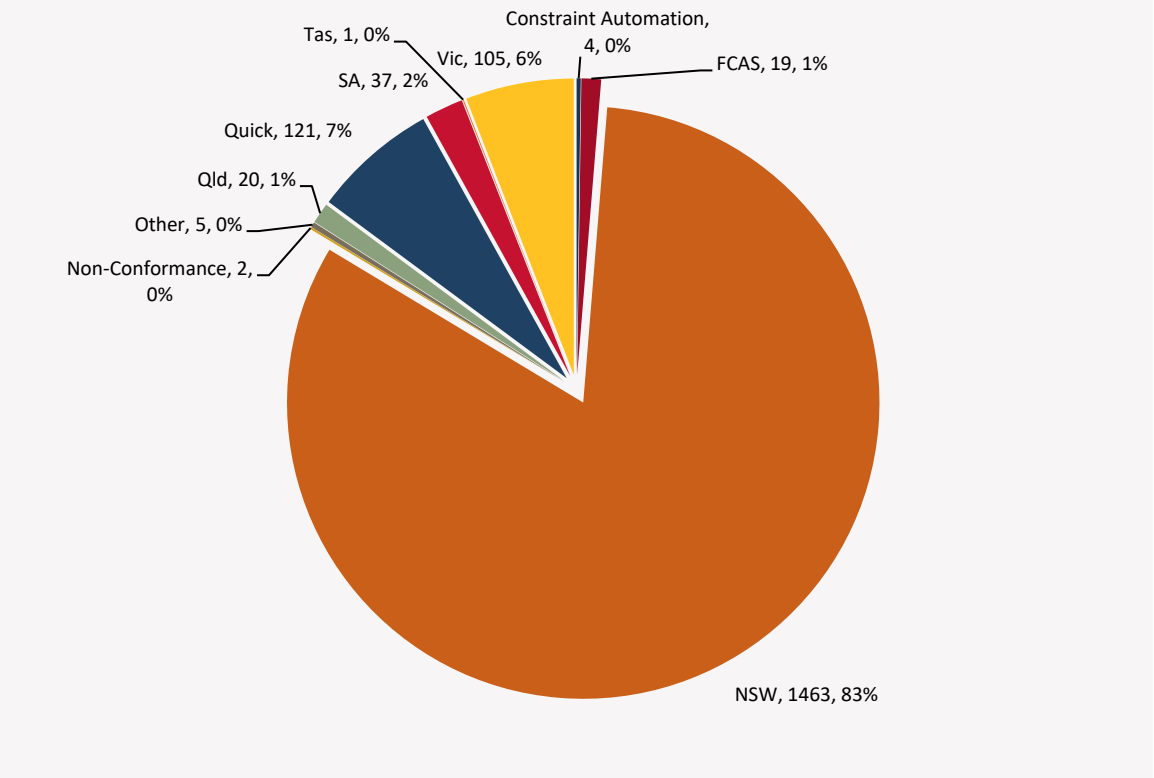
3.1 Constraint Equation Changes

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