AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

February 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 February 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	1859 (154.91)	22/01/2020
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	1858 (154.83)	20/01/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	1664 (138.66)	31/01/2020
V_MLMO_VS_LB_CAN_50	Out = Moorabool to Mortlake 500 kV line, TRTS 500kV centre CB fail timer set to zero, No.2 HYTS line CB at APD OPEN, limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement. Constraint swamp out if MOPS/DUNDWF generating.	1556 (129.66)	3/12/2019
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)	1433 (119.41)	1/01/2020
SA_HYSE2	SA / Eastern separation between Heywood and South East (HYTS - SESS), SA to Victoria on VicSA upper limit of 0 MW	994 (82.83)	6/02/2020
SA_HYSE1	SA / Eastern separation between Heywood and South East (HYTS - SESS), Victoria to SA on VicSA upper limit of 0 MW	820 (68.33)	6/02/2020
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	700 (58.33)	2/10/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V::N_ESTN_HYSE_VD	SA / ESTN separation between Heywood and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 1	673 (56.08)	1/07/2015
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	626 (52.16)	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
N>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	1,978,295	22/01/2020
F_S+TL_L6_OD	Lower 6 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load	1,731,593	14/02/2020
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)	1,481,156	1/01/2020
F_S+TL_L60_OD	Lower 60 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load	1,236,102	14/02/2020
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	1,197,789	31/01/2020
F_S+TL_L5_OD	Lower 5 min Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load	1,190,850	14/02/2020
F_S+TG_R60_150	Raise 60 sec Service Requirement for a 150 MW SA Generation Event	1,116,140	14/02/2020
F_S++MOPS1_R6_1	Raise 6 sec Service Requirement for SA Generation Event, where Mortlake 1 is the largest generation risk in SA (MOPS connects to SA), Segment 1	703,917	31/01/2020
F_S+TL_L6_0150	Lower 6 sec Service Requirement for a 150 MW SA Network (Load) Event	648,160	14/02/2020
F_S+TG_R5_150	Raise 5 min Service Requirement for a 150 MW SA Generation Event	490,859	14/02/2020

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

2.3 Top 10 violating constraint equations

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

Table 3 Top 10 violating constraint equations

Table 1 – Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
F_S++MOPS1_R6_1	Raise 6 sec Service Requirement for SA Generation Event, where Mortlake 1 is the largest generation risk in SA (MOPS connects to SA), Segment 1	81 (6.75)	31/01/2020
F_S+TL_L6_OD	Lower 6 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load	68 (5.66)	14/02/2020
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	52 (4.33)	31/01/2020
NRM_SA1_VIC1	Negative Residue Management constraint for SA to VIC flow	38 (3.16)	12/06/2012
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	17 (1.41)	21/12/2018
F_S++MOPS1_R6_2	Raise 6 sec Service Requirement for SA Generation Event, where Mortlake 1 is the largest generation risk in SA (MOPS connects to SA), Segment 2	8 (0.66)	31/01/2020
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	4 (0.33)	4/05/2018
N>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	4 (0.33)	22/01/2020
F_S++MOPS2_R6_2	Raise 6 sec Service Requirement for SA Generation Event, where Mortlake 2 is the largest generation risk in SA (MOPS connects to SA), Segment 2	3 (0.25)	31/01/2020
V_MLMO_VS_LB_CAN_50	Out = Moorabool to Mortlake 500 kV line, TRTS 500kV centre CB fail timer set to zero, No.2 HYTS line CB at APD OPEN, limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement. Constraint swamp out if MOPS/DUNDWF generating.	2 (0.16)	3/12/2019

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_S++MOPS1_R6_1	Constraint equation violated for 81 DIs, 56 of which were consecutive. Max violation of 35.62 MW occurred on 01/02/2020 at 1415 hrs. Constraint equation violated due to South Australia raise 6 second service being less than the requirement. This is a result of the separation event between Victoria and South Australia. These equations have since been revoked and control schemes are implemented to manage the loss of the Mortlake Unit.

Constraint Equation ID (System Normal Bold)	Description
F_S+TL_L6_OD	Constraint equation violated for 68 DIs, 22 of which were consecutive. Max violation of 52 MW occurred on 02/02/2020 at 0445 hrs. Constraint equation violation due to South Australia lower 6 second service availability less than requirement, as a result of the separation event between Victoria and South Australia.
F_S++MOPS2_R6_1	Constraint equation violated for 52 DIs, 14 of which were consecutive. Max violation of 21.69 MW occurred on 01/02/2020 at 1445 hrs. Constraint equation violated due to the same reason as F_S++MOPS_R6_1
NRM_SA1_VIC1	Constraint equation violated for 38 DIs, 11 of which were consecutive. Max violation of 33.24 MW occurred on 5/02/2020 at 1305 hrs. Constraint violation occurred due to competing requirement with the Heywood and Murraylink interconnector export limits set by VSML_-150 and SA_HYSE1 respectively.
NSA_V_NPSD_100	Constraint equation violated for 17 DIs, 11 of which were consecutive. Max violation of 87.06 MW occurred on 29/02/2020 at 0905 hrs. Constraint equation violated due to Newport PS being limited by its start-up profile
F_S++MOPS1_R6_2	Constraint equation violated for 8 non-consecutive DIs, with max violation of 15.04 MW occurring on 01/02/2020 at 1415 hrs. Constraint equation violated due to the same reason as F_S++MOPS_R6_1
F_T_AUFLS2_R6	Constraint equation violated for 4 DIs with max violation of 18.96 MW occurring on 19/02/2020 at 1350 hrs. Constraint equation violation occurred due to Tasmania raise 6 second service being less than the requirement.
N>N-NIL_CLDP_1	Constraint equation violated for 4 DIs with max violation of 2.77 MW occurring on 07/02/2020 at 1140 hrs. Constraint violation due to Finley solar farm and Coleambally solar farm being limited by its ramp down rate.
F_S++MOPS2_R6_2	Constraint equation violated for 3 DIs on 01/02/2020 0850 hrs to 0900 hrs. Max violation of 4.7 MW occurring at 0850 hrs. Constraint equation violated due to the same reason as F_S++MOPS_R6_1
V_MLMO_VS_LB_CAN_50	Constraint equation violated for 2 DIs on 18/02/2020 at 1655 hrs and 1700 hrs with max violation of 32.06 MW occurring at 1655 hrs. Constraint equation violated due to competing requirement with import limit set by F_S+MLMO_TL_L6_2.

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)
#V-SA_I_E	V-SA Export	V-SA. * -1 = 30 (Wt = 360)	3003 (250.25)	-29.46 (-10.0)
F_S+MLMO_TL_L60	V-SA Import	Out= Moorabool to Mortlake 500kV line, SA Lower 60 sec requirement for loss of Heywood to Tarrone to Haunted Gully to Moorabool 500kV lines	1475 (122.92)	-33.9 (-169.66)
V_MLMO_VS_LB_CAN_50	V-SA Export	Out = Moorabool to Mortlake 500 kV line, TRTS 500kV centre CB fail timer set to zero, No.2 HYTS line CB at APD OPEN, limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement. Constraint swamp out if MOPS/DUNDWF generating.	1408 (117.33)	-46.24 (50.64)
SA_HYSE2	V-SA Import	SA / Eastern separation between Heywood and South East (HYTS - SESS), SA to Victoria on VicSA upper limit of 0 MW	989	0.0

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
			(82.42)	(0.0)
F_QNV++MG_R6	T-V-MNSP1 Export	Raise 6 sec Service Requirement for QLD, NSW, and VIC Generation Event, Basslink able to transfer FCAS	752 (62.67)	23.19 (445.01)
S>V_NIL_NIL_RBNW	V-S-MNSP1 Import	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	698 (58.17)	-149.56 (-193.47)
V::N_ESTN_HYSE_VD	VIC1-NSW1 Export	SA / ESTN separation between Heywood and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 1	668 (55.67)	771.89 (1309.1)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	664 (55.33)	121.63 (445.0)
V::N_ESTN_HYSE_VD	V-S-MNSP1 Export	SA / ESTN separation between Heywood and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 1	640 (53.33)	-109.19 (206.09)
N_X_MBTE_3A	N-Q-MNSP1 Export	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	626 (52.17)	-35.26 (-9.1)

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_4D69957C	27/02/2020 10:20 to 27/02/2020 13:50	RTCA indicated that the trip of the Calvale to Wurdong 275 kV line would result in the thermal overload of Raglan to Larcom Creek 275 kV line. The constraint automation was invoked on the Raglan to Larcom Creek line to manage overloading on trip of the Calvale to Wurdong line.

2.5.1 Further Investigation

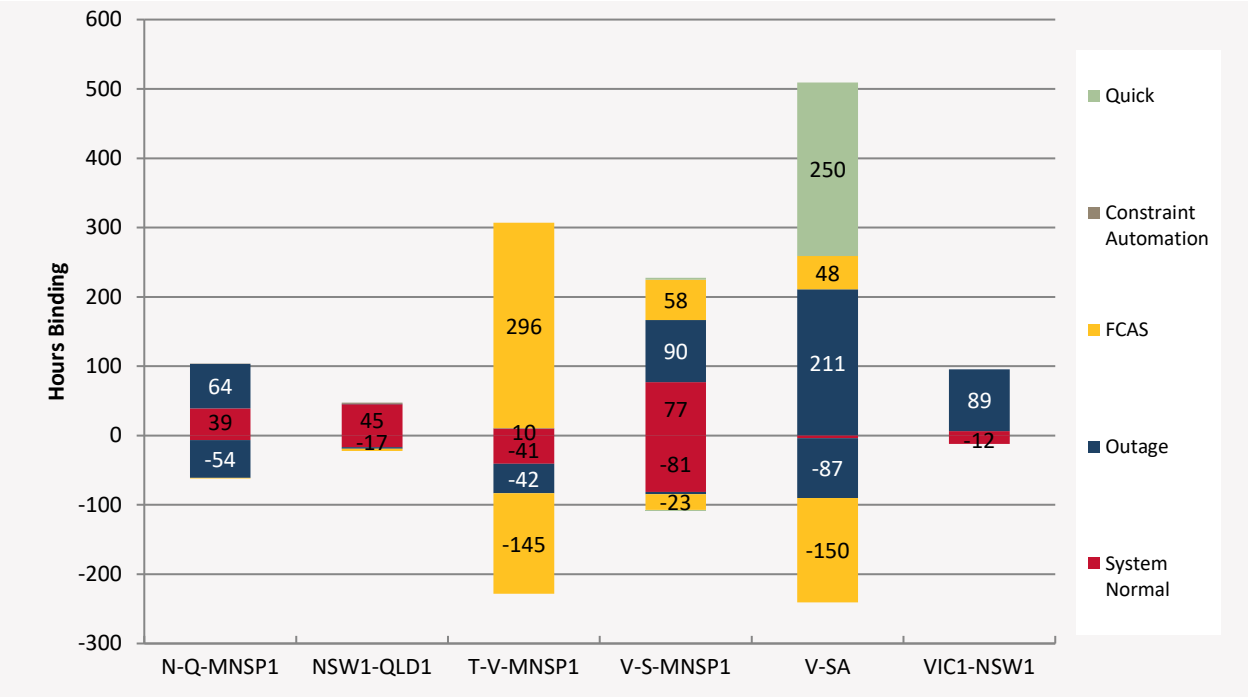
CA_BRIS_4D69957C: A new system normal constraint equation (Q>>NIL_CLWU_RGLC) was built to manage the thermal overload of the Raglan to Larcom Creek 275 line on trip of the Calvale to Wurdone 275 kV line.

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.

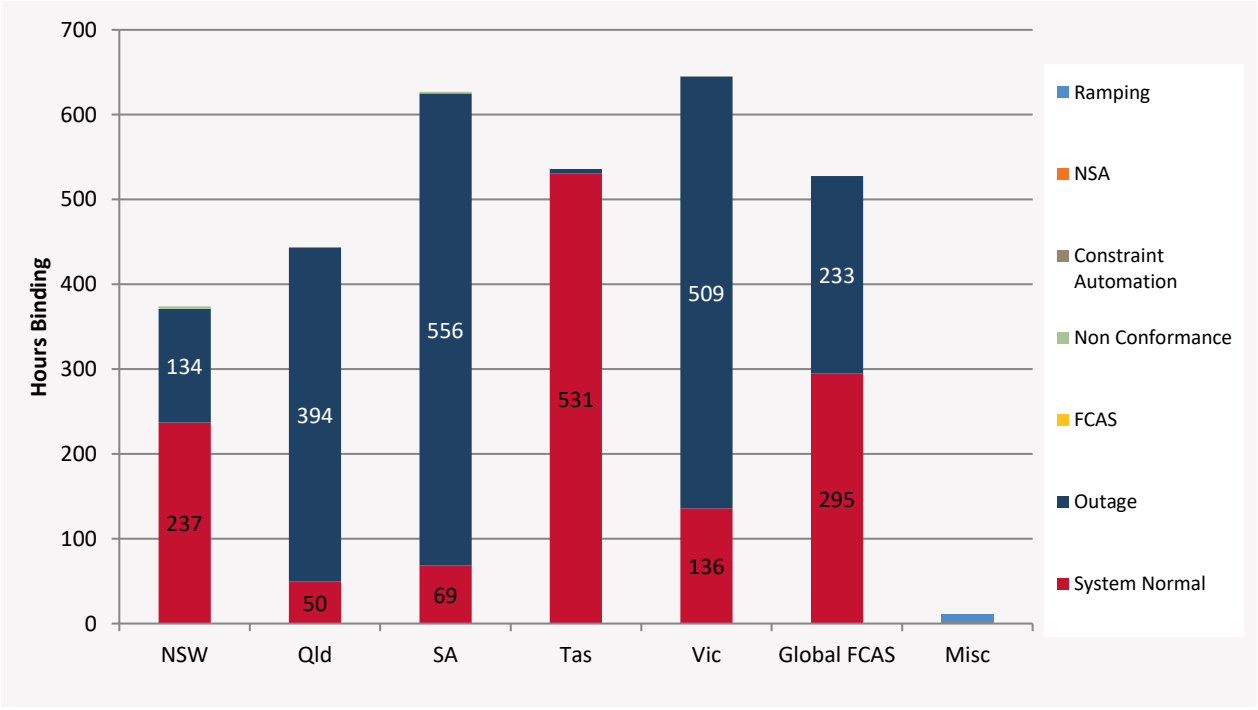
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

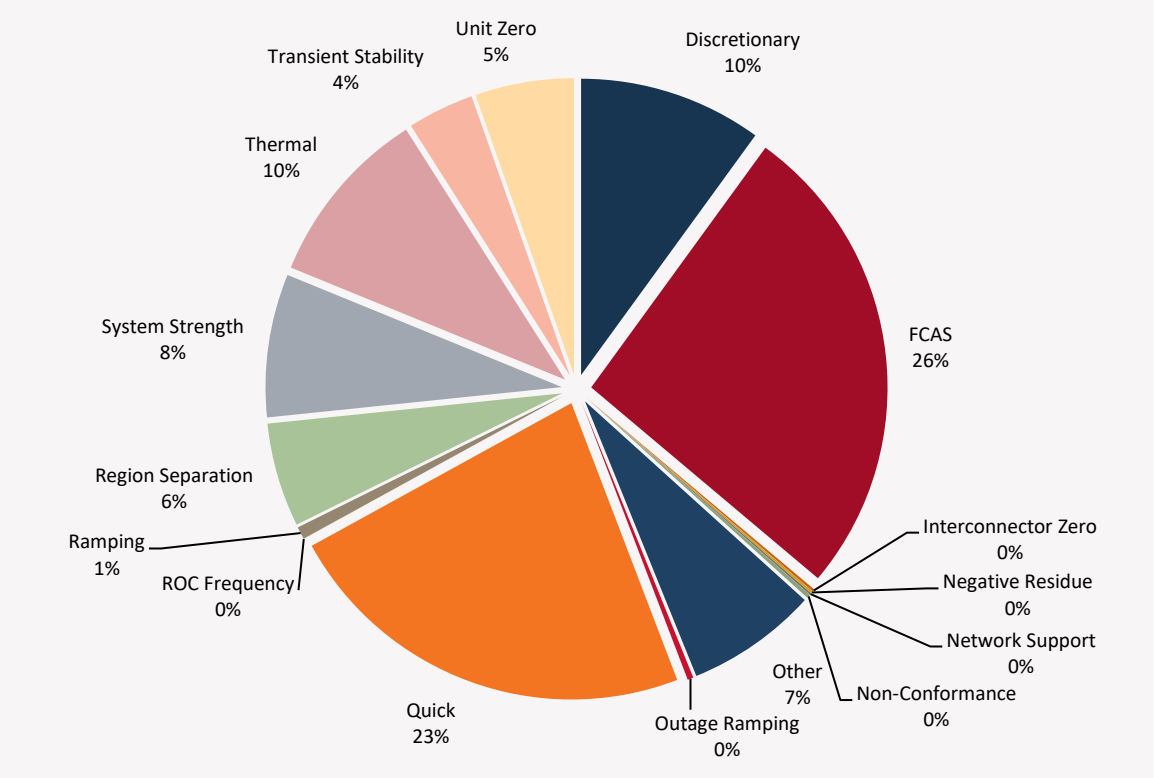
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

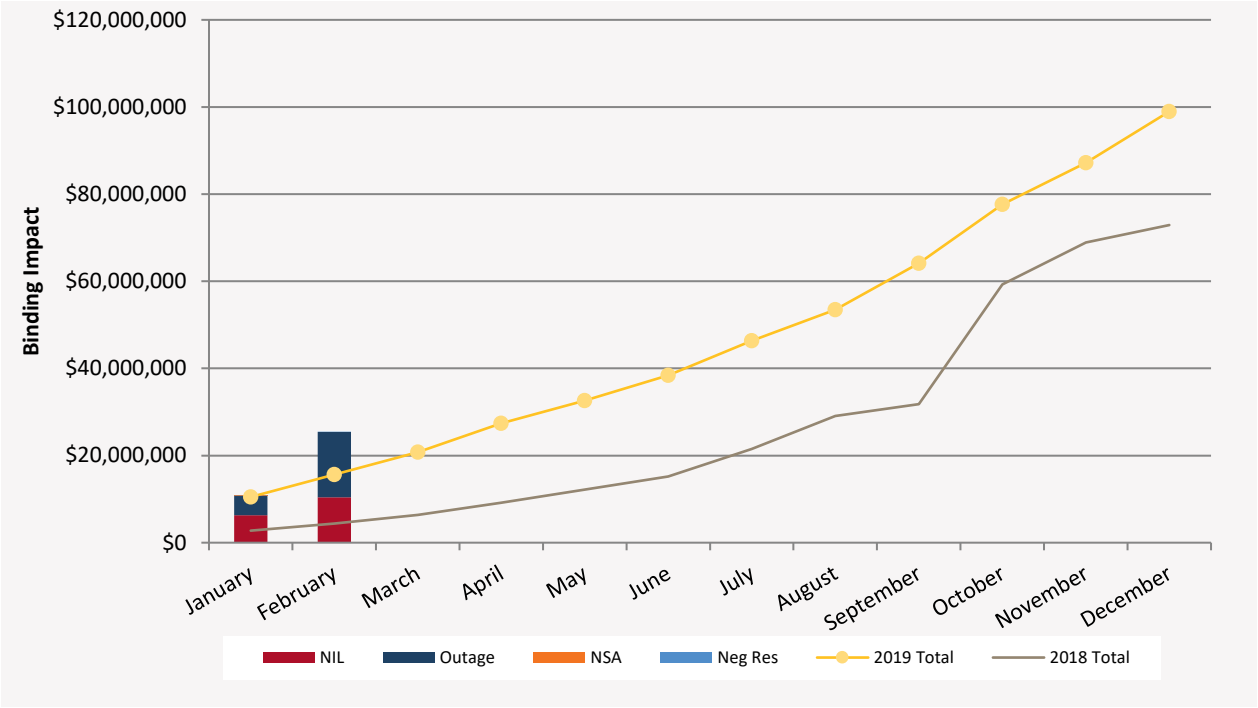
Figure 3 Binding by limit type



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.	47	53,865% (63.)	8,134% (6.46)
V::N_ESTN_HYSE_VE	SA / ESTN separation between Heywood and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 2	29	4,912% (161.03)	235% (44.12)
V::N_ESTN_HYSE_VD	SA / ESTN separation between Heywood and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 1	113	4,912% (168.59)	91.53% (56.5)
V_MLMO_VS_LB_CAN_50	Out = Moorabool to Mortlake 500 kV line, TRTS 500kV centre CB fail timer set to zero, No.2 HYTS line CB at APD OPEN, limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement. Constraint swamp out if MOPS/DUNDWF generating.	339	2,918% (91.47)	174% (17.94)
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	4	417% (158.89)	163% (82.84)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
	generating >=80 MW when Dalymple Battery (i.e. both Gen and Load component) is I/S]			
V::N_ESTN_HYSE_VA	SA / ESTN separation between Heywood and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink TAS to VIC, VIC accelerates, segment 1	4	363% (134.05)	113.71% (62.02)
V::N_ESTN_HYSE_QB	SA / ESTN separation between Heywood and South East Sub, avoid transient instability for fault and trip of a Hazelwood to Sth Morang 500kV line, Basslink TAS to VIC, QLD accelerates, segment 2	5	311% (230.87)	99.82% (120.73)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	111	288% (299.79)	10.49% (31.87)
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	3	285% (190.39)	232% (128.69)
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	24	205% (151.7)	84.43% (151.7)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_ESTN_MLMOHG_Q1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_ESTN_MLMOHG_Q2: Investigated and no improvement can be made to the constraint equation at this stage.

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

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

V_MLMO_VS_LB_CAN_50: Investigated and no improvement can be made to the constraint equation at this stage.

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

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.

V_MURRAWRWF_MAX: 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 February 2020.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Maryrorough Solar Farm	25 February 2020	QLD1	New Generator

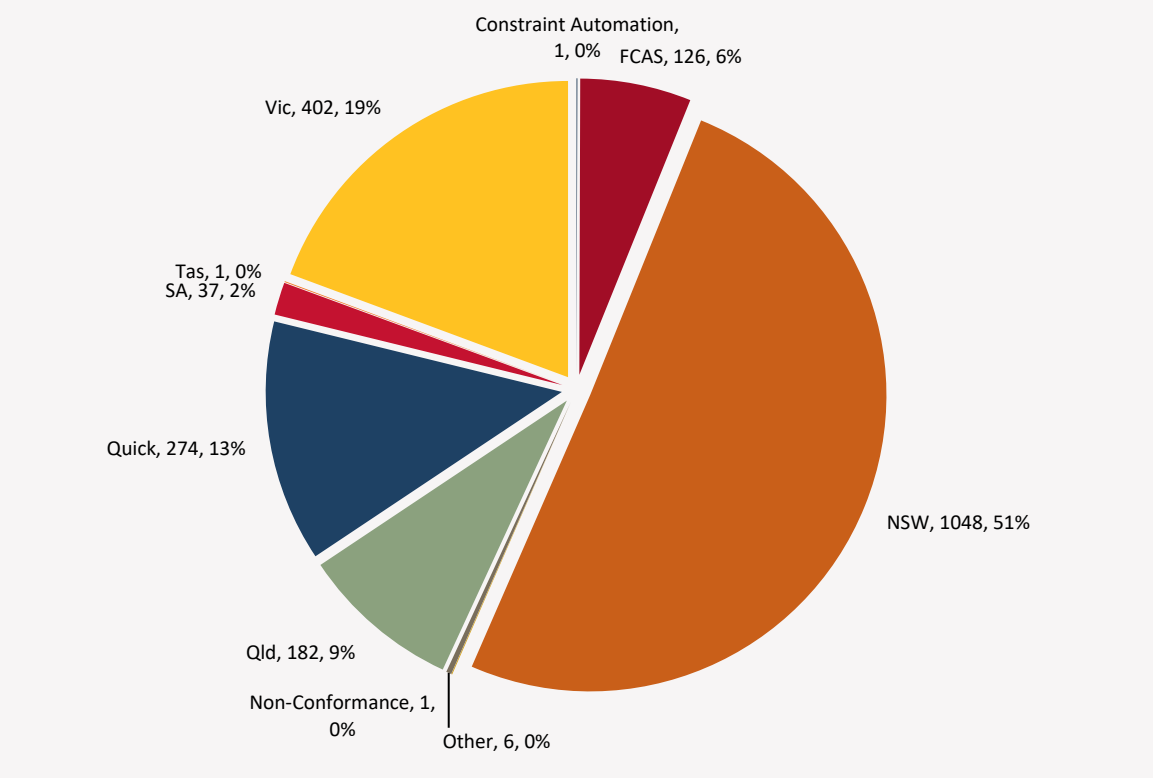
3.1 Constraint Equation Changes

The following pie chart indicates the regional location of constraint equation changes. For details on individual constraint equation changes refer to the Weekly Constraint Library Changes Report[2] or the constraint equations in the MMS Data Model.[3]

[2] AEMO. *NEM Weekly Constraint Library Changes Report*. Available at: http://www.nemweb.com.au/REPORTS/CURRENT/Weekly_Constraint_Reports/

[3] AEMO. *MMS Data Model*. Available at: 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