AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

December 2019

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 December 2019. 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	3109 (259.08)	12/12/2019
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	1747 (145.58)	2/12/2019
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	1113 (92.75)	6/11/2019
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	976 (81.33)	2/10/2019
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	840 (70.0)	11/01/2019
V^^SML_NSWRB_2	Out = NSW Murraylink runback scheme, VIC to SA transfer limit on Murraylink to avoid voltage collapse at Red Cliffs for the loss of either the Darlington Point to Balranald (X5) or Balranald to Buronga (X3) 220kV lines	710 (59.16)	14/10/2019
N^^Q_NIL_B1	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	676 (56.33)	6/12/2017
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	657 (54.75)	15/05/2019
V_GANWRSF_FLT_25	Limit Gannawarra solar farm upper limit to 25 MW to manage post contingent voltage oscillation	650 (54.16)	4/09/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	572 (47.66)	21/08/2013

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	3,275,931	12/12/2019
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	862,252	11/01/2019
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.	567,656	8/01/2020
V_GANWRSF_FLT_25	Limit Gannawarra solar farm upper limit to 25 MW to manage post contingent voltage oscillation	554,055	4/09/2019
V_OWF_TGTSNRBHTN_30	Out= Nil, TGTS-HTN-NRB-TGTS sub-transmission loop OPEN, Limit Oaklands Hill Windfarm upper limit to 30 MW, DS only. Swamp out if the loop closed.	489,841	5/05/2017
Q>NIL_COLNVSF1	Out = Nil, Limit Collinsville Solar Farm to thermal rating of Powerlink's RMU	372,646	5/11/2019
Q_CS_1100	Qld Central to Qld South upper transfer limit of 1100MW (discretionary)	331,722	29/05/2019
V_OAKHILL_TFB_42	Out = Nil, Oaklands Hill Windfarm upper limit of 42.7 MW due to Oaklands Hill windfarm TFB mode operation, DS only. Swamp out if TFB mode is OFF	275,344	18/04/2017
Q_STR_233310_MEWF_39	Limit MT Emerald WF to 75% of max capacity (#39 turbine) if Kareeya > = 2 and Stanwell >= 3 and Callide >= 3 and Gladstone> = 3 and total of Stanwell, Callide and Gladstone >=10. Swamp during night. Limit to zero otherwise.	240,776	22/10/2019

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.

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Change Date
V^^SML_NSWRB_2	Out = NSW Murraylink runback scheme, VIC to SA transfer limit on Murraylink to avoid voltage collapse at Red Cliffs for the loss of either the Darlington Point to Balranald (X5) or Balranald to Buronga (X3) 220kV lines	240,622	14/10/2019

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
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	70 (5.83)	23/09/2019
Q:NIL_OAKEY2SF	Limit Oakey 2 solar farm to 0MW when Oakey GT is online to prevent transient instability for 3 phase fault at Tangkam	53 (4.41)	2/09/2019
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	29 (2.41)	21/12/2018
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	8 (0.66)	4/05/2018
N>N-LSTN_TE_C1	Out= Lismore to Tenterfield (96L), avoid O/L Koolkhan to Lismore (967), on trip of Coffs Harbour to Lismore (89), Swamp out when all 3 directlink cable O/S, Feedback, TG formulation in PD/ST	5 (0.41)	21/08/2013
NSA_Q_GSTONE34_150	Gladstone 3+4 >= 150 for Network Support Agreement	4 (0.33)	7/10/2015
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	3 (0.25)	2/12/2016
NSA_V_BDL02_20	Bairnsdale Unit 2 >= 20 MW for Network Support Agreement	3 (0.25)	21/08/2013
S_PLN_ISL_01	Out = Cultana to Yadnarie (via Middleback Tee) 132kV line, Port Lincoln units 1 and 2 islanded	3 (0.25)	13/03/2014
N_COLEASF1_ZERO	Coleambally solar farm upper limit of 0 MW	2 (0.16)	19/06/2018

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
V^SML_BUDP_3	Constraint violated for 70 consecutive DIs on 30/12/2019 from 1505 hrs to 2050 hrs with a max violation of 79.94 MW occurring at 1740 hrs. Constraint equation violated due to competing requirements with import constraint S>V_NIL_NIL_RBNW. VSAT did not show any voltage violations and the limit is under review.
Q:NIL_OAKEY2SF	Constraint equation violated for 53 DIs occurring consecutively on 2/12/2019 1655 hrs to 1840 hrs and 3/12/2019 1705 hrs to 2020 hrs. Max violations of 10 MW occurred on 2/12/2019 at 1655 to 1705 hrs and on 03/12/2019 at 1700 to 1705 hrs. Constraint equation violation is due to Oakey 2 solar farm non-conforming.
NSA_V_NPSD_100	Constraint equation violated for 29 DIs, 27 of which were consecutive. Max violation of 85 MW occurred on 24/12/2019 0035 and 0040 hrs. Constraint equation violation due to Newport PS being limited by its start-up profile.
F_T_AUFLS2_R6	Constraint equation violated for 8 non-consecutive DIs with max violation of 26.9 MW occurring on 27/12/2019 1400 hrs. Constraint equation violated due to Tasmania raise 6 second service availability being less than the requirement.
N>N-LSTN_TE_C1	Constraint equation violated for 5 DIs with max violation of 40 MW occurring on 1/12/2019 1410 hrs. Constraint equation violated due to competing requirements with import limit QNTE_ROC.
NSA_Q_GSTONE34_150	Constraint equation violated for 4 DIs with max violation of 1 MW occurring on 8/12/2019 1030, 1105, 1110 and 1230 hrs. Constraint equation violation due to Gladstone being stranded in FCAS requirement.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 3 DIs on 15/12/2019 1005 hrs and 20/12/2019 0105 hrs and 0115 hrs, with max violation of 22.72 MW occurring on 20/12/2019 0105 hrs. Constraint equation violated due to the same reason as F_T_AUFLS2_R6
NSA_V_BDL02_20	Constraint equation violated for 3 DI's where max violation of 20 MW occurred on 9/12/2019 from 1530 hrs to 1540 hrs. Constraint equation violated due to Bairnsdale unit 2 being limited by its start-up profile.
S_PLN_ISL_01	Constraint equation violated for 3 DIs on 30/12/2019 1525 hrs, 1530 hrs and 1550 hrs with max violation of 7.08 MW occurring on 1530 hrs. Constraint equation violated for 3 DIs on 30/12/2019 1525 hrs, 1530 hrs and 1550 hrs with max violation of 7.08 MW occurring on 1530 hrs. Constraint equation violated due to Port Lincoln Unit 1 starting up to supply local load due to bushfires resulting in islanded conditions.
N_COLEASF1_ZERO	Constraint equation violated on 30/12/2019 1505 hrs and 1510 hrs with max violation of 67.41 MW occurring on 1505 hrs. Constraint violation due to Coleambally 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++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1223 (101.92)	85.24 (478.0)
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	1120 (93.33)	-94.54 (-445.0)
N^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	1113 (92.75)	-405.83 (-818.24)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1050 (87.5)	101.43 (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	976 (81.33)	-154.79 (-194.09)
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	782 (65.17)	-151.43 (-445.0)
V^^SML_NSWRB_2	V-S-MNSP1 Export	Out = NSW Murraylink runback scheme, VIC to SA transfer limit on Murraylink to avoid voltage collapse at Red Cliffs for the loss of either the Darlington Point to Balranald (X5) or Balranald to Buronga (X3) 220kV lines	707 (58.92)	83.49 (216.81)
N^^Q_NIL_B1	NSW1-QLD1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	675 (56.25)	306.41 (480.21)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	645 (53.75)	840.16 (1189.92)
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	631 (52.58)	-31.12 (-445.0)

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 3 – Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_BRIS_4D0EE093	20/12/2019 15:00 to 20/12/2019 17:55	RTCA indicated that the trip of an Eildon PS to Mount Beauty 220 kV line would result in thermal overload of the parallel Eildon PS to Mount Beauty 220kV line. The Eildon PS to Mount Beauty 220kV line was de-rated due to high temperatures. Constraint automation was used to prevent overloading of the Eildon PS to Mount Beauty line on trip of the parallel line.

2.5.1 Further Investigation

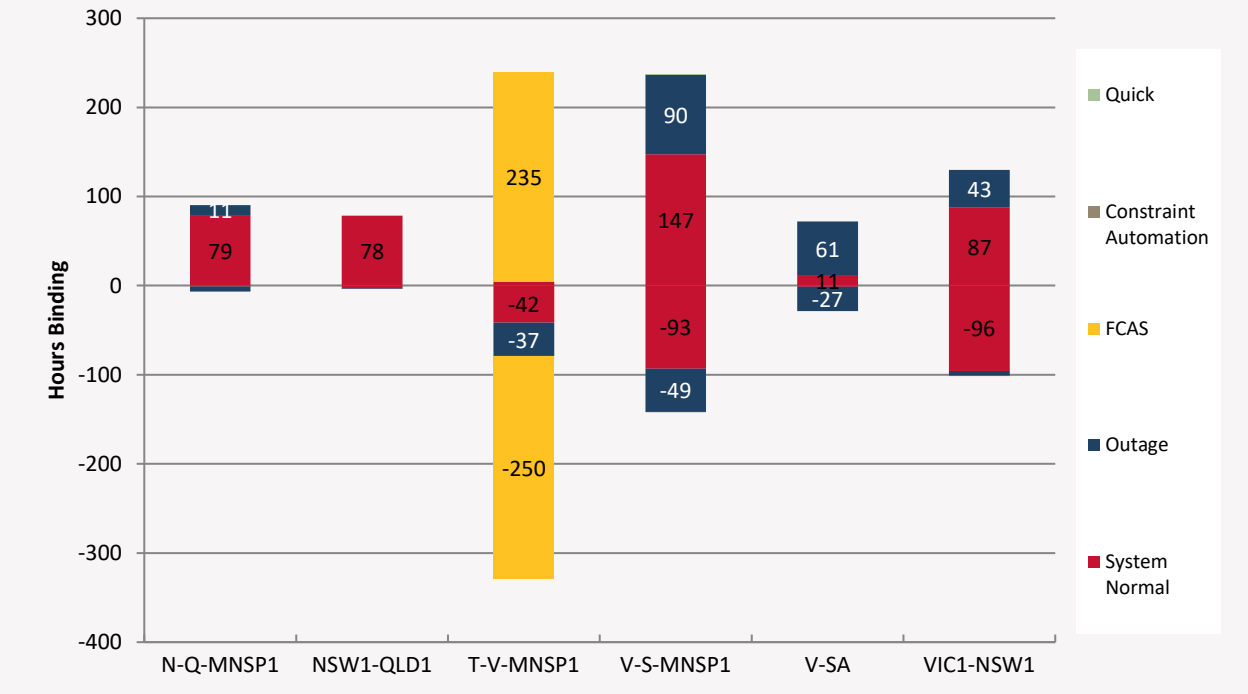
CA_BRIS_4D0EE093: A new system normal constraint equation (V>>V_NIL_19) has been built to manage the overload of an Eildon PS to Mount Beauty 220kV line on trip of the parallel line.

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.

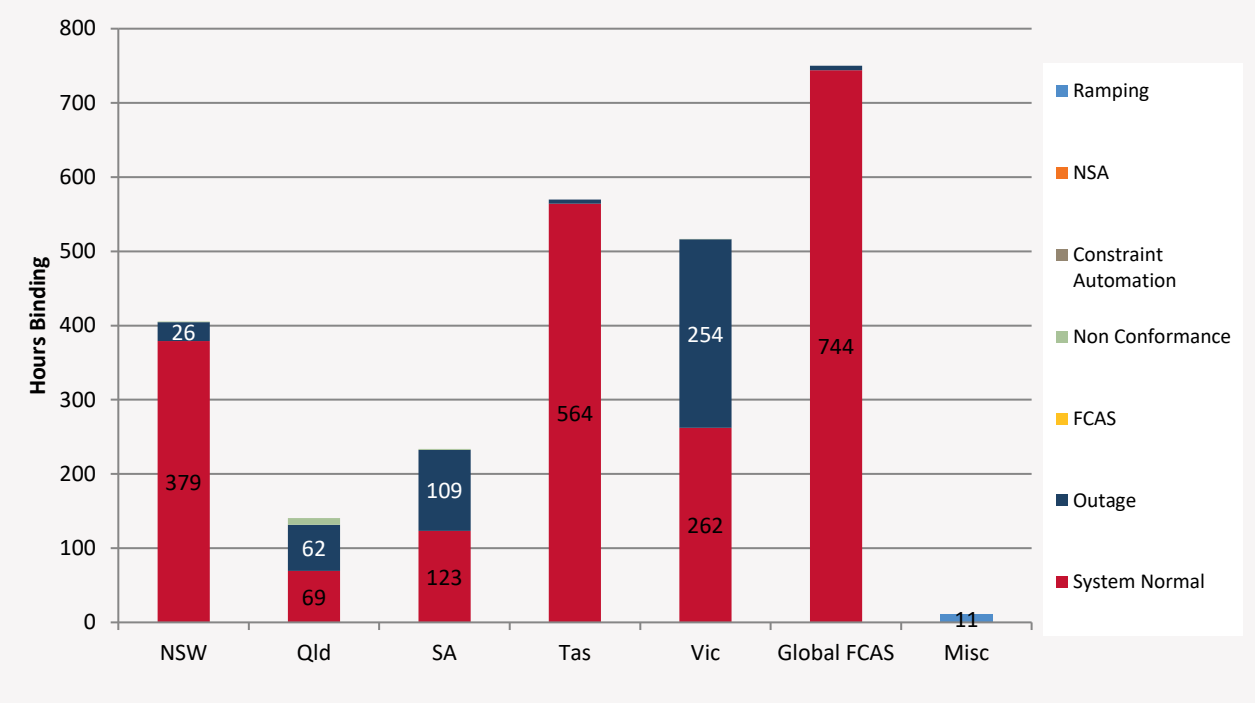
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

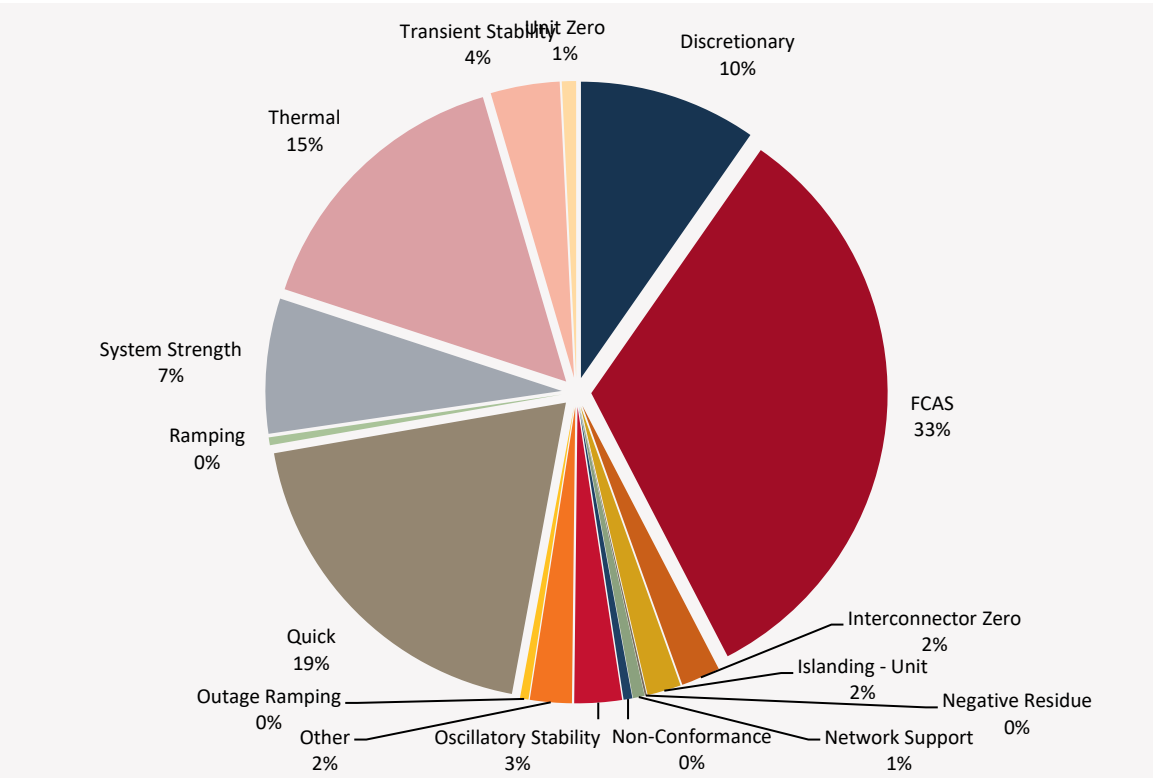
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for December 2019 that the different types of constraint equations bound.

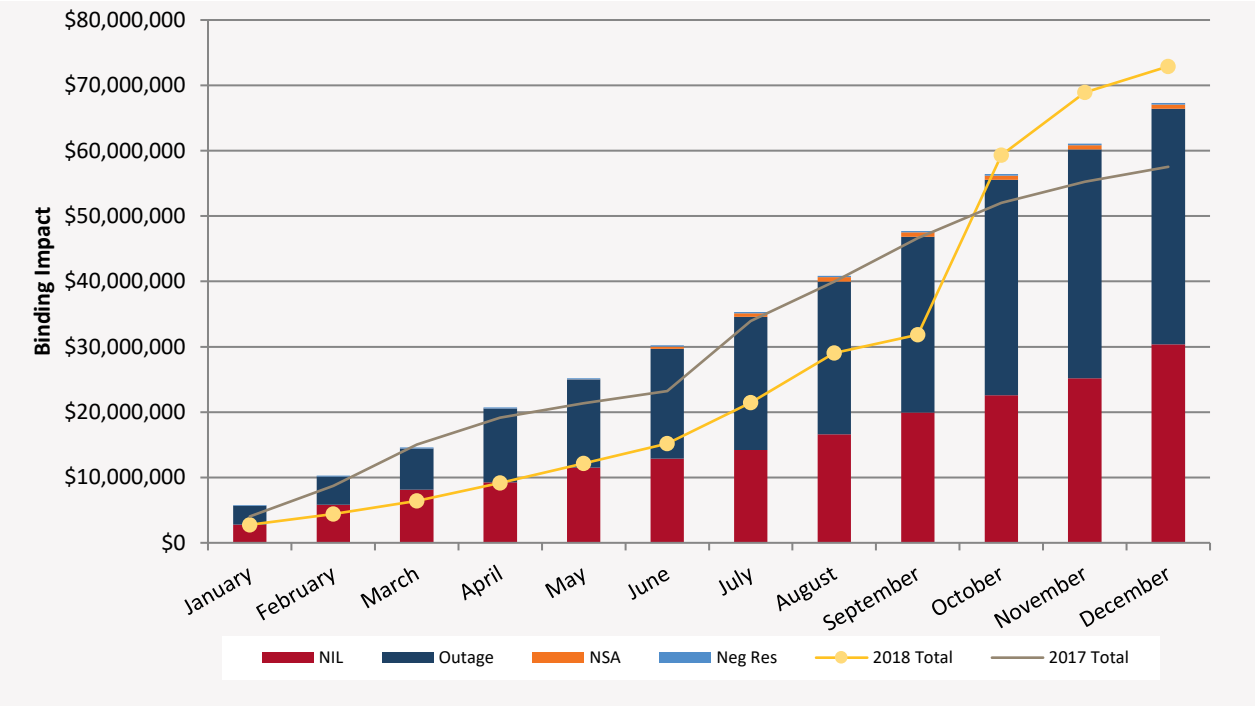
Figure 3 Binding by limit type



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
V^SML_HORC_3	Out = Horsham to Murra Warra to Red Cliffs 220kV line OR Murra Warra to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	19	29,914% (54.9)	1,715% (21.51)
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.	105	881% (288.69)	108.06% (91.78)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	105	434% (391.55)	39.62% (61.25)
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to not exceed 75 MW with Broken Hill solar generating	6	227% (170.)	146.67% (100.)
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]	10	225% (132.36)	164% (93.11)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	283	155% (489.64)	19.46% (79.64)
V^^SML_NSWRB_2	Out = NSW Murraylink runback scheme, VIC to SA transfer limit on Murraylink to avoid voltage collapse at Red Cliffs for the loss of either the Darlington Point to Balranald (X5) or Balranald to Buronga (X3) 220kV lines	146	102.41% (167.)	44.61% (76.09)
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	19	100.% (74.)	52.48% (73.57)
Q_STR_233310_MEWF_39	Limit MT Emerald WF to 75% of max capacity (#39 turbine) if Kareeya > = 2 and Stanwell >= 3 and Callide >= 3 and Gladstone> = 3 and total of Stanwell, Callide and Gladstone >=10. Swamp during night. Limit to zero otherwise.	7	100.% (134.99)	100.% (134.99)
Q_STR_233310_SMSF_38	Limit Sun Metal SF to 50% of max capacity (#38 inverters) if Kareeya > = 2 and Stanwell > = 3 and Callide > = 3 and Gladstone > = 3 and total of Stanwell, Callide and Gladstone > =10. Limit to zero otherwise.	8	100.% (61.)	100.% (61.)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^SML_HORC_3: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_HWSM_V2: Investigated and no improvement can be made to the constraint equations at this stage.

V_T_NIL_FCSPS: This constraint equation uses analog values for the load enabled for the FCSPS in Pre-dispatch. This value can change quickly in dispatch and this is not possible to predict in Pre-dispatch. No changes proposed.

N_SILVERWF_MAX: 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.

N^^V_NIL_1: The Pre-dispatch formulation for this constraint equation was recalculated in early November 2017 (with an update to the limit advice). No further improvements can be made at this stage.

V^^SML_NSWRB_2: 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_STR_233310_MEWF_39: Investigated and no improvement can be made to the constraint equation at this stage.

Q_STR_233310_SMSF_38: 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 December 2019.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Nevertire Solar Farm	2 December 2019	NSW	New Generator
Limondale 2 Solar Farm	24 December 2019	NSW	New Generator
Granville Harbour Wind Farm	3 December 2019	TAS	New Generator

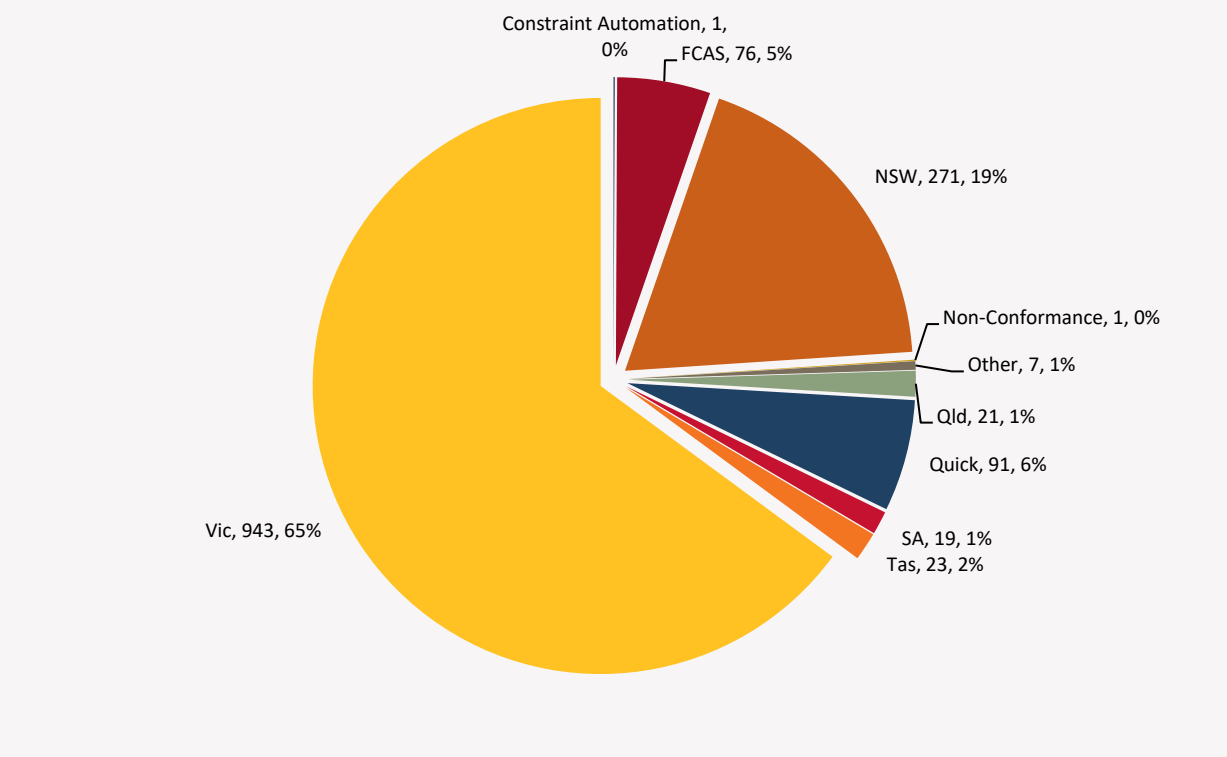
3.1 Constraint Equation Changes

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