Monthly Constraint Report

April 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 April 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^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	3290 (274.16)	19/12/2018
Q^^NIL_QNI_SRAR	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	976 (81.33)	11/04/2019
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	834 (69.5)	20/12/2016
V_MTMERCER_ZERO	Mt Mercer Windfarm upper limit of 0 MW	791 (65.91)	22/10/2013
N>N-NIL_MBDU	Out = Nil, avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the other Mullumbimby to Dunoon line (9U7 or 9U6), Feedback	367 (30.58)	11/01/2019
N_SILVERTWF_FLT_0	Limit Silverton Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	360 (30.0)	4/02/2019
V_KIATAWF_FLT_0	Limit Kiata Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	359 (29.91)	13/02/2019
V_WEMENSF_45_21INV	Limit Wemen Solar Farm upper limit to 45 MW with max 21 inverter available, upper limit set to 0 MW if number of inverter available exceed 21. This is to manage voltage oscillation	337 (28.08)	21/03/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 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.	327 (27.25)	5/12/2018
V_GANWRSF_FLT_0	Limit Gannawarra solar farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	325 (27.08)	7/12/2018

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
V_MTMERCER_ZERO	Mt Mercer Windfarm upper limit of 0 MW	887,088	22/10/2013
S-DLBAT-G_0	Discretionary upper limit for Dalrymple Battery (generation component) of 0 MW	652,500	7/08/2018
N_SILVERTWF_FLT_0	Limit Silverton Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	401,151	4/02/2019
V_WEMENSF_45_21INV	Limit Wemen Solar Farm upper limit to 45 MW with max 21 inverter available, upper limit set to 0 MW if number of inverter available exceed 21. This is to manage voltage oscillation	376,510	21/03/2019
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 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.	363,341	5/12/2018
V_BANSF_45_22INV	Limit Bannerton Solar Farm upper limit to 45 MW with max 22 inverter available, upper limit set to 0 MW if number of inverter available exceed 22. This is to manage voltage oscillation	358,643	21/03/2019
V_BANNERTSF_FLT_0	Limit Bannerton Solar Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	354,634	7/01/2019
V_WEMENSF_FLT_0	Limit Wemen Solar Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	291,167	7/12/2018

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
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to not exceed 45 MW with Broken Hill solar generating or 131 MW otherwise	277,699	8/04/2019
V_CWWF_5	Crowlands Wind Farm total upper limit of 5 MW, limit to manage MW risk of islanding	209,370	2/04/2019

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 0.

Table 3 Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
T>T_BUSH1_220	Out = Burnie to Sheffield 220kV line, West Coast 220/110 kV parallel open, avoid O/L a Sheffield 220/110kV transformer for loss of the other Sheffield 220/110kV transformer	19 (1.58)	22/03/2017
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	5 (0.41)	4/05/2018
V^SML_ARWB_3	Out = Ararat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	5 (0.41)	15/08/2017
F_T+NIL_WF_TG_R60	Out= Nil, Tasmania Raise 60 sec requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS	1 (0.08)	12/04/2016
F_T+NIL_WF_TG_R5	Out= Nil, Tasmania Raise 5 min requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS	1 (0.08)	12/04/2016
T_T_FASH_8_N-2	Out = Nil, loss of both Farrell to Sheffield lines declared credible, Farrell 220 kV bus NOT split, Mackintosh P/S unavailable, West Coast 220/110 kV parallel open, limit all West Coast generation >= 90% of West Coast load	1 (0.08)	16/02/2018
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	1 (0.08)	20/12/2016
F_T++NIL_MG_RECL_R5	Out = Nil, Raise 5 min requirement for a Tasmania Reclassified Woolnorth Generation Event, Basslink able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	1 (0.08)	2/12/2016
F_T+NIL_MG_R5	Out = Nil, Raise 5 min requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	1 (0.08)	12/04/2016
F_T+NIL_MG_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	1 (0.08)	12/04/2016

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
T>T_BUSH1_220	Constraint equation violated for 19 DIs, 17 of which were consecutive. Max violation of 18.03 MW occurred on 01/04/2019 at 0700hrs. Constraint equation violated due to Devils Gate hydro unit being unavailable.
F_T_AUFLS2_R6	Constraint equation violated for 5 DIs. Max violation of 7.41 MW occurred on 17/04/2019 at 1545hrs. Constraint equation violated due to Tasmania raise 6 seconds service availability being less than the requirement.
V^SML_ARWB_3	Constraint equation violated for 5 DIs. Max violation of 5.12 MW occurred on 04/04/2019 at 0650hrs. Constraint equation violated due to competing requirement with the Murraylink interconnector import limit set by SVML_FLT_070.
F_T+NIL_WF_TG_R60	Constraint equation violated for 1 DI on 09/04/2019 at 0330hrs with a violation degree of 58.62 MW. Constraint equation violated due to Tasmania raise 60 seconds service availability being less than the requirement.
F_T+NIL_WF_TG_R5	Constraint equation violated for 1 DI on 09/04/2019 at 0330hrs with a violation degree of 50.69 MW. Constraint equation violated due to Tasmania raise 5 minutes service availability being less than the requirement.
T_T_FASH_8_N-2	Constraint equation violated for 1 DI on 05/04/2019 at 2250hrs with a violation degree of 24.37 MW. Constraint equation violated due to both Farrell to Sheffield 220kV lines were declared as credible due to lightning. Constraint invoked without ramping (this is normal practice for constraint invocation).
V_T_NIL_FCSPS	Constraint equation violated for 1 DI on 09/04/2019 at 0330hrs with a violation degree of 14.43 MW. Constraint equation violated due to competing requirement with the Basslink interconnector export limit set by F_MAIN++NIL_MG_R6.
F_T++NIL_MG_RECL_R5	Constraint equation violated for 1 DI on 16/04/2019 at 2120hrs with a violation degree of 9.49 MW. Constraint equation violated due to the same reason as F_T+NIL_WF_TG_R5.
F_T+NIL_MG_R5	Constraint equation violated for 1 DI on 09/04/2019 at 0330hrs with a violation degree of 9.25 MW. Constraint equation violated due to the same reason as F_T+NIL_WF_TG_R5.
F_T+NIL_MG_R6	Constraint equation violated for 1 DI on 07/04/2019 at 0030hrs with a violation degree of 4.45 MW. Constraint equation violated due to the same reason as F_T_AUFLS2_R6.

2.4 Top 10 binding interconnector limit setters

Binding constraint equations can set the interconnector limits for each of the interconnectors on the constraint equation left-hand side (LHS). Table 5 lists the top (by binding hours) interconnector limit setters for all the interconnectors in the NEM and for each direction on that interconnector.

Table 5 Top 10 binding interconnector limit setters

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	3290 (274.17)	-259.46 (-783.57)
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	1593 (132.75)	-97.07 (-477.99)

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	1229 (102.42)	-129.89 (471.31)
Q^^NIL_QNI_SRAR	NSW1-QLD1 Import	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	976 (81.33)	-899.28 (-1035.15)
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	684 (57.0)	-219.58 (-477.0)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	667 (55.58)	-320.91 (-477.88)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	596 (49.67)	-126.17 (470.08)
N>N-NIL_MBDU	N-Q-MNSP1 Import	Out = Nil, avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the other Mullumbimby to Dunoon line (9U7 or 9U6), Feedback	367 (30.58)	-186.17 (-199.5)
Q::N_NIL_AR_2L-G	NSW1-QLD1 Import	Out=Nil, limit Qld to NSW on QNI to avoid transient instability for a 2L-G fault at Armidale	268 (22.33)	-1025.06 (-1110.48)
V^SML_BAWB_3	V-S-MNSP1 Export	Out = Ballarat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	245 (20.42)	-35.27 (-15.5)

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.

2.5.1 Further Investigation

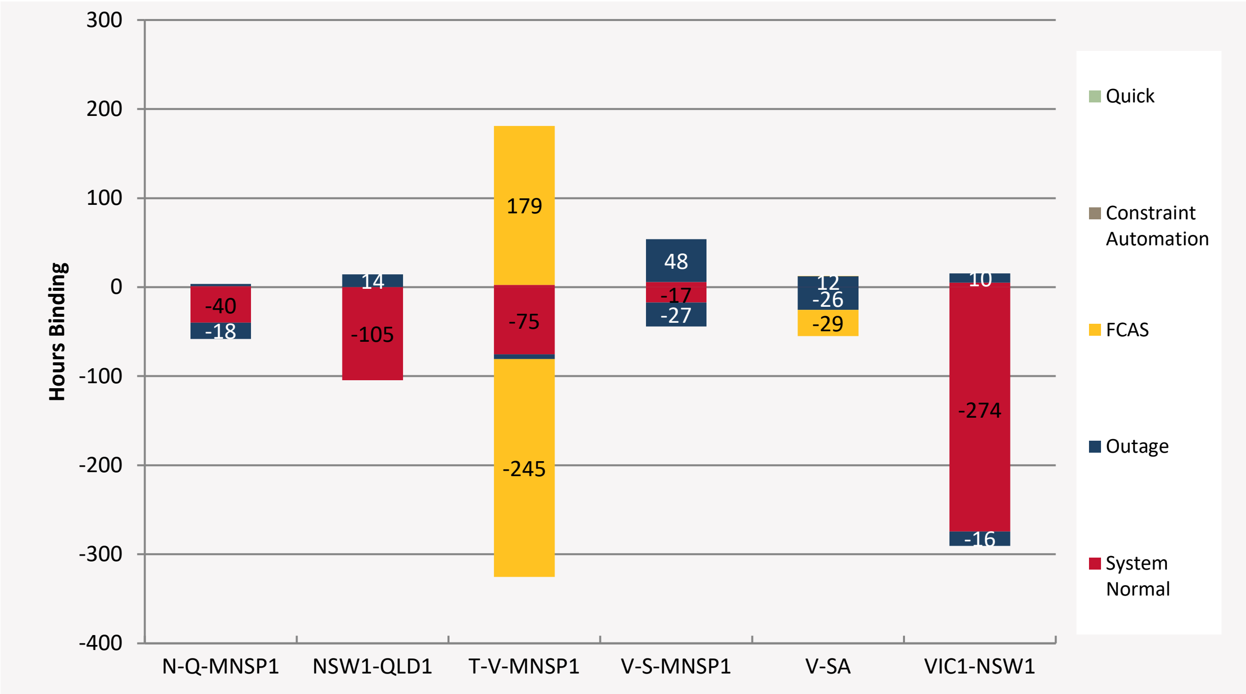
Non-real-time constraint automation was not used.

2.6 Binding Dispatch Hours

This section examines the number of hours of binding constraint equations on each interconnector and by region. The results are further categorized into five types: system normal, outage, FCAS (both outage and system normal), constraint automation and quick constraints.

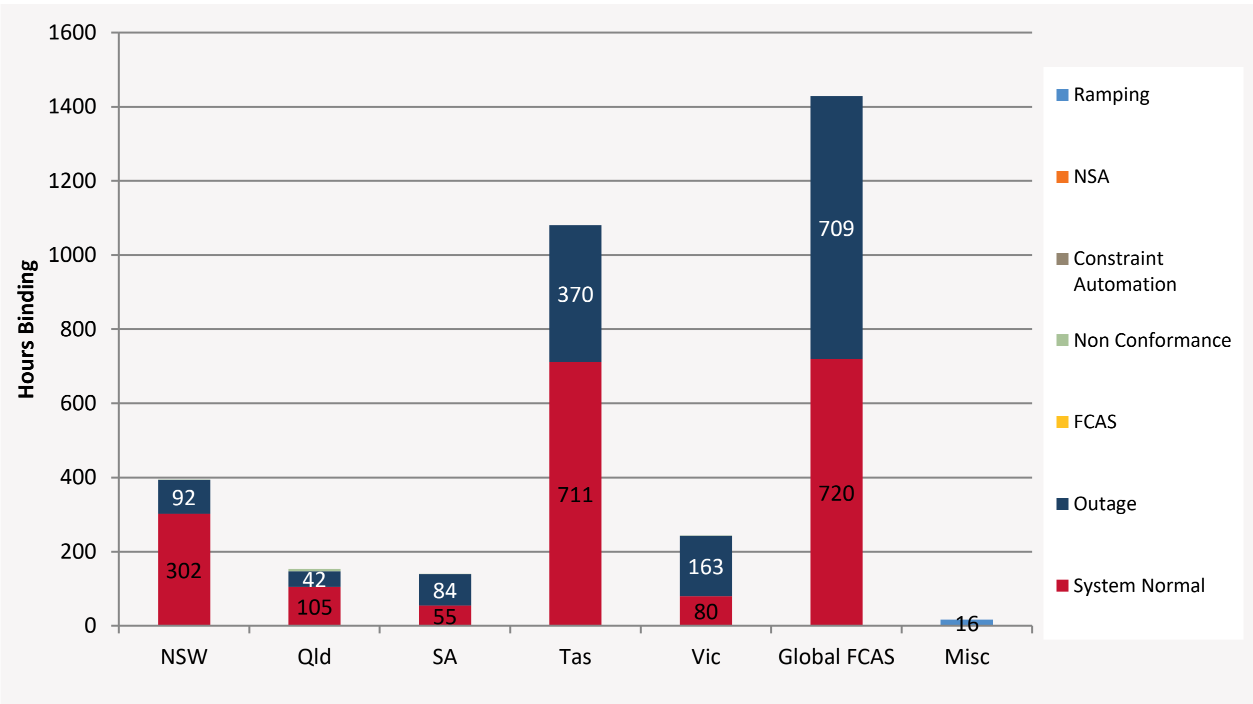
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

Figure 1 Interconnector binding dispatch hours



The regional comparison graph below uses the same categories as in Figure 1 as well as non-conformance, network support agreement and ramping. Constraint equations that cross a region boundary are allocated to the sending end region. Global FCAS covers both global and mainland requirements.

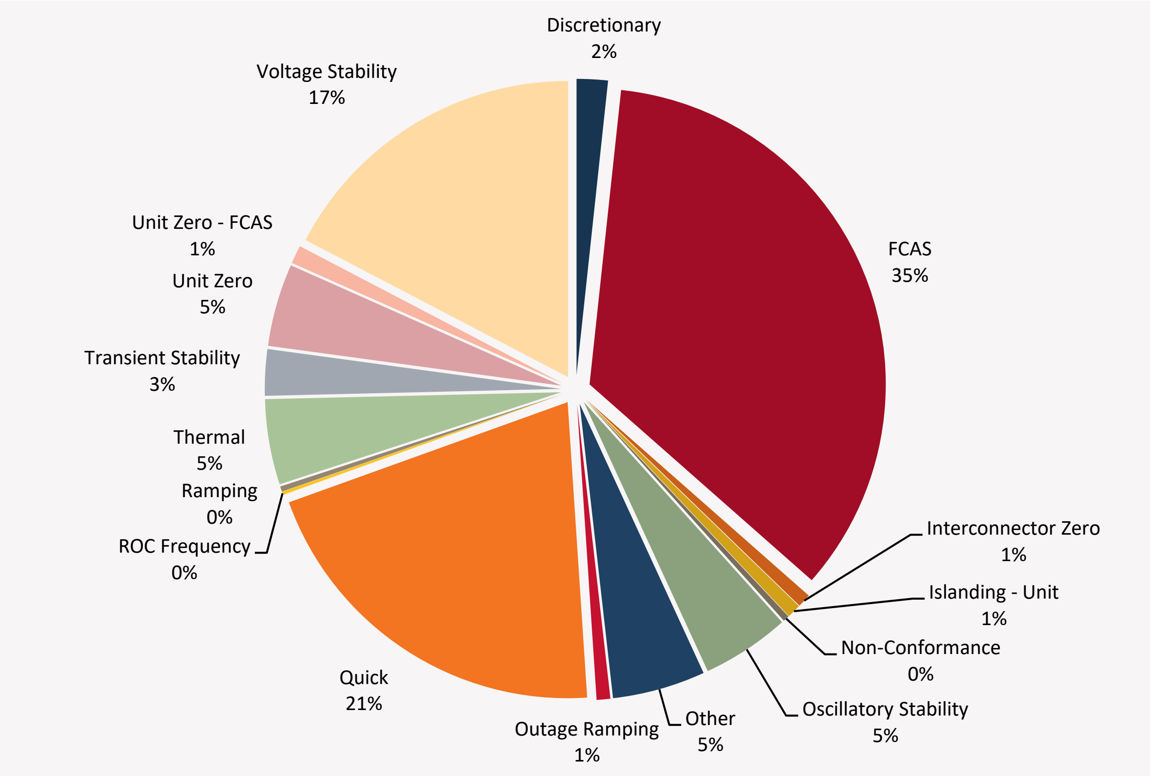
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

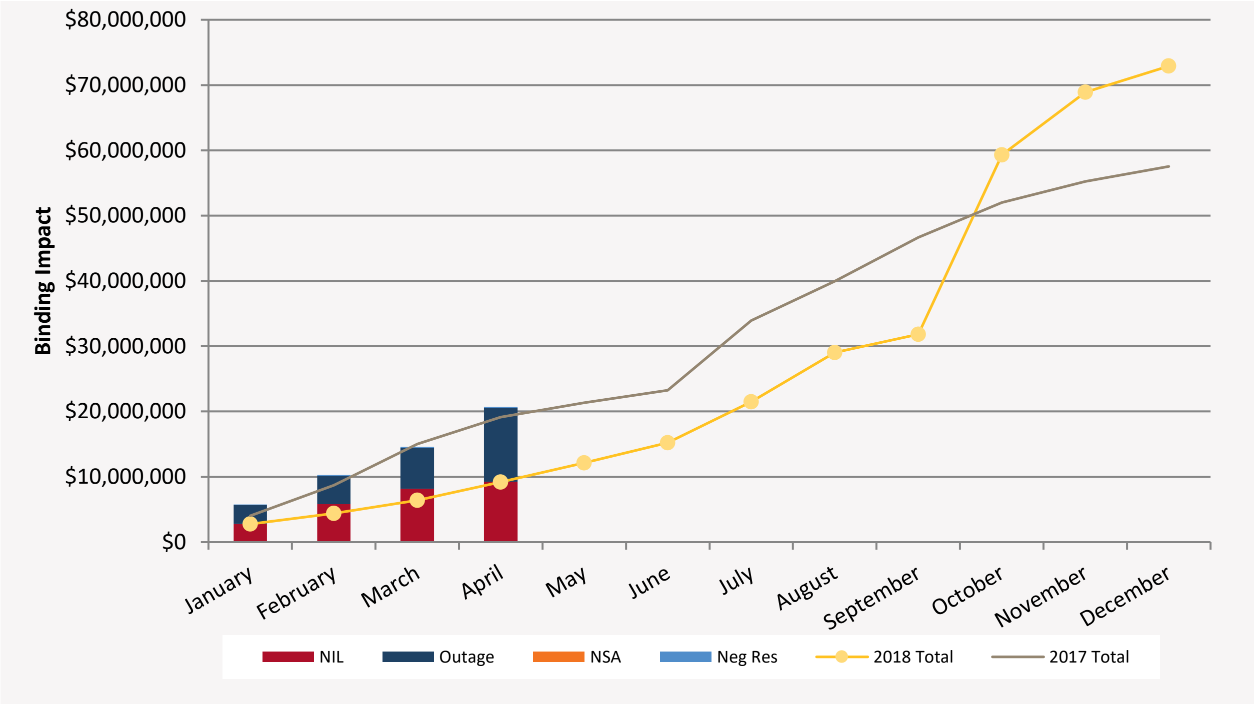
Figure 3 Binding by limit type



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_BANSF_45_22INV	Limit Bannerton Solar Farm upper limit to 45 MW with max 22 inverter available, upper limit set to 0 MW if number of inverter available exceed 22. This is to manage voltage oscillation	9	4,500,000 % (45.)	4,500,00 0% (45.)
V_KARSF_45_21INV	Limit Karadoc Solar Farm upper limit to 45 MW with max 21 inverter available, upper limit set to 0 MW if number of inverter available exceed 21. This is to manage voltage oscillation	11	4,500,000 % (45.)	2,045,50 9% (45.)
V_WEMENSF_45_21INV	Limit Wemen Solar Farm upper limit to 45 MW with max 21 inverter available, upper limit set to 0 MW if number of inverter available exceed 21. This is to manage voltage oscillation	31	4,500,000 % (45.)	290,416 % (45.)
N_BKHSF_30_44INV	Limit Broken Hill Solar Farm upper limit to 30 MW with max 44 inverter available, upper limit set to 0 MW if number of inverter available exceed 44. This is to manage voltage oscillation	53	3,000,000 % (30.)	3,000,00 0% (30.)
V_GANNSF_30_12INV	Limit Gannawarra Solar Farm upper limit to 30 MW with max 12 inverter available, upper limit set to 0 MW if number of inverter available exceed 12. This is to manage voltage oscillation	13	3,000,000 % (30.)	692,385 % (30.)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V_KARSF_20_8INV	Limit Karadoc Solar Farm upper limit to 20 MW with max 8 inverter available, upper limit set to 0 MW if number of inverter available exceed 8. This is to manage voltage oscillation	12	2,000,000 % (20.)	1,000,050% (20.)
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	12	15,945% (56.83)	2,612% (40.56)
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.	29	944% (212.61)	97.69% (80.59)
V^SML_BAWB_3	Out = Ballarat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	41	515% (38.08)	59.04% (14.73)
V^SML_ARWB_3	Out = Ararat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	48	421% (66.43)	60.47% (27.91)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V_KARSF_45_21INV, V_BANSF_45_22INV, V_WEMENSF_45_21INV, V_GANNSF_30_12INV, V_KARSF_20_8INV, V::N_HWSM_V1, V^SML_ARWB_3, V^SML_BAWB_3: 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 April 2019.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Beryl Solar Farm	11 April 2019	NSW	New Generator

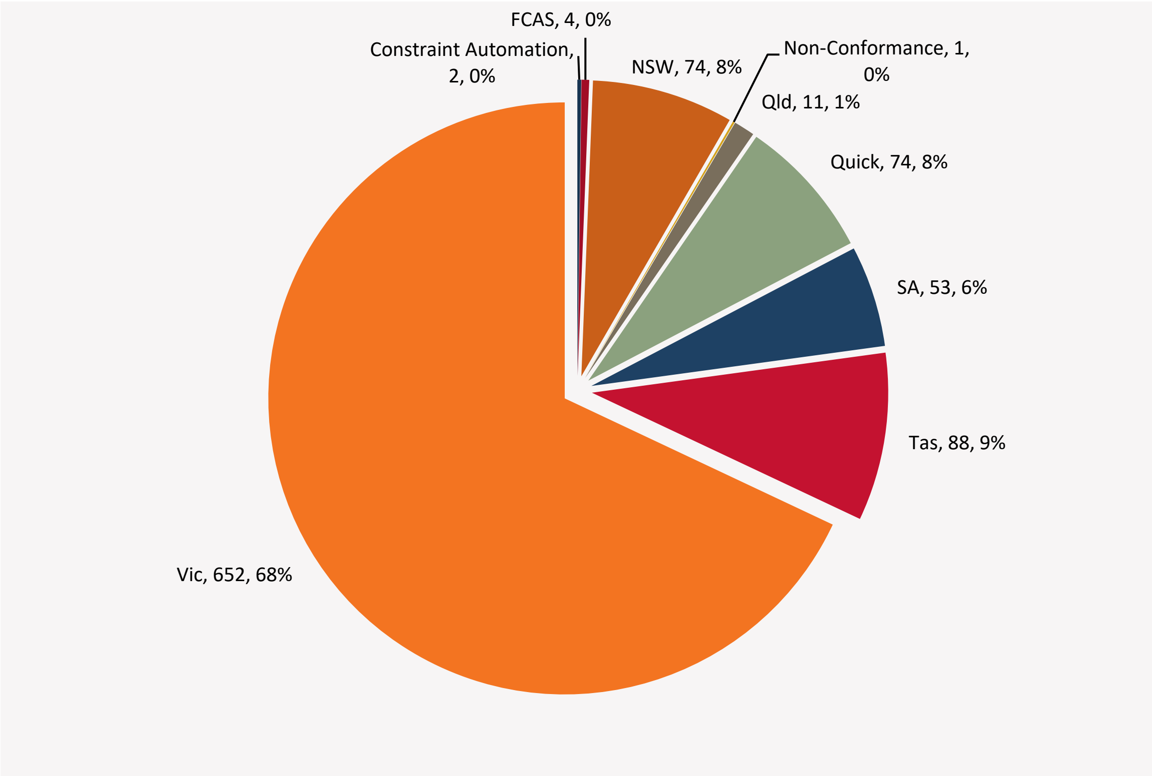
3.1 Constraint Equation Changes

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