AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

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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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Contents

Tables

Figures

1. Introduction

This report details constraint equation performance and transmission congestion related issues for February 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
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	3290 (274.16)	20/12/2016
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	2792 (232.66)	19/12/2018
N_SILVERWF_MAX	Limit MW output of Silverton wind farm to be not exceed 45 MW with Broken Hill solar generating or 76 MW otherwise	855 (71.25)	13/11/2018
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_KARADSF_FLT_0	Limit Karadoc solar farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	649 (54.08)	13/12/2018
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	649 (54.08)	7/12/2018
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	340 (28.33)	13/02/2019
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	237 (19.75)	25/01/2019

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.	230 (19.16)	5/12/2018
T_TAMARCCGT_GCS	Tamar Valley 220 kV CCGT Generation Control Scheme (GCS) constraint to manage effective size of generation contingency for loss of Tamar CCGT. Limit output of Tamar CCGT based on load available and/or armed for shedding by Tamar GCS.	226 (18.83)	6/06/2016

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_SILVERWF_MAX	Limit MW output of Silverton wind farm to be not exceed 45 MW with Broken Hill solar generating or 76 MW otherwise	931,896	13/11/2018
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	929,334	11/01/2019
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	300,399	4/05/2018
T_TAMARCCGT_GCS	Tamar Valley 220 kV CCGT Generation Control Scheme (GCS) constraint to manage effective size of generation contingency for loss of Tamar CCGT. Limit output of Tamar CCGT based on load available and/or armed for shedding by Tamar GCS.	258,925	6/06/2016
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	237,666	7/01/2019
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	217,264	19/12/2018
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	215,009	20/12/2016
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength	208,653	5/12/2018

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
	requirements. Automatically swamps out when required HIGH combination is online.		
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	149,097	12/04/2016
F_T+NIL_WF_TG_R6	Out= Nil, Tasmania Raise 6 sec requirement for loss of a Smithton to Woolnorth or Norwood to Scotsdale tee Derby line, Basslink unable to transfer FCAS	146,785	12/04/2016

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

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	20 (1.66)	4/05/2018
N>N-ARKS_TE_A1	Out= Armidale to Kempsey (965), avoid O/L Armidale to Coffs Harbour (96C) on trip of Armidale to Coffs Harbour (87), Swamp out when all 3 directlink cable O/S, Feedback, TG formulation in PD/ST	12 (1.0)	25/02/2016
S_LB2WF_CONF	Out= Nil; Limit Lake Bonney 2 & 3 generation based on DVAR availability.	8 (0.66)	7/08/2015
NSA_V_BDL01_20	Bairnsdale Unit 1 >= 20 MW for Network Support Agreement	8 (0.66)	21/08/2013
N>N-NIL_TE_E1	Out= Nil, avoid Armidale to CoffsHarbour (96C) O/L on Armidale-CoffsHarbour(87) trip; Feedback, TG formulation in PD/ST	5 (0.41)	11/01/2019
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	2 (0.16)	12/04/2016
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	2 (0.16)	7/12/2018
NSA_V_BDL02_20	Bairnsdale Unit 2 >= 20 MW for Network Support Agreement	2 (0.16)	21/08/2013
T_TAMARCCGT_GCS	Tamar Valley 220 kV CCGT Generation Control Scheme (GCS) constraint to manage effective size of generation contingency for loss of Tamar CCGT. Limit output of Tamar CCGT based on load available and/or armed for shedding by Tamar GCS.	1 (0.08)	6/06/2016
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

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_T_AUFLS2_R6	Constraint equation violated for 20 non-consecutive DIs. Max violation of 14.18 MW occurred on 12/02/2019 at 1915hrs. Constraint equation violated due to Tasmania raise 6 second service availability being less than the requirement.
N>N-ARKS_TE_A1	Constraint equation violated for 12 non-consecutive DIs. Max violation of 37.11 MW occurred on 09/02/2019 at 1655hrs. Constraint equation violated due to competing requirement with the Terranora interconnector import limit set by QNTE_ROC.
S_LB2WF_CONF	Constraint equation violated for 8 consecutive DIs. Max violation of 77.16 MW occurred on 04/02/2019 at 1445 hrs. Constraint equation violated due to failed SCADA.
NSA_V_BDL01_20	Constraint equation violated for 8 non-consecutive DIs with a violation degree of 20 MW for each DI. Constraint equation violated due to Bairnsdale unit 1 being limited by its start-up profile.
N>N-NIL_TE_E1	Constraint equation violated for 5 DIs. Max violation of 25.7 MW occurred on 12/02/2019 at 1725hrs. Constraint equation violated due to competing requirement with the Terranora interconnector import limit set by QNTE_ROC.
F_T+NIL_MG_R6	Constraint equation violated for 2 DIs. Max violation of 51.15 MW occurred on 06/02/2019 at 0735hrs. Constraint equation violated due to Tasmania raise 6 second service availability from generators being less than requirement.
V_WEMENSF_FLT_0	Constraint equation violated for 2 DIs. Max violation of 14.1 MW occurred on 18/02/2019 at 1520hrs. Constraint equation violated due to control issue at Wemen Solar Farm and the issue has been fixed.
NSA_V_BDL02_20	Constraint equation violated for 2 DIs on 12/02/2019 from 1705hrs to 1710hrs with a violation degree of 20 MW for each DI. Constraint equation violated due to unexpected trip of the Bairnsdale unit 2. A new bid for the Bairnsdale unit 1 was submitted after the trip.
T_TAMARCCGT_GCS	Constraint equation violated for 1 DI on 06/02/2019 at 0735hrs with a violation degree of 31.03 MW. Constraint equation violated due to Tamar Valley CCGT being limited by its ramp down rate.
F_T+NIL_WF_TG_R5	Constraint equation violated for 1 DI on 12/02/2019 at 0835hrs with a violation degree of 21.51 MW. Constraint equation violated due to Tasmania raise 5 min service availability being less than requirement.

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_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	3061 (255.08)	-336.28 (-477.78)
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	2792 (232.67)	-162.57 (-807.06)

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	779 (64.92)	-62.37 (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	778 (64.83)	-154.65 (-463.35)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	299 (24.92)	-136.56 (478.0)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	263 (21.92)	-84.38 (478.0)
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	237 (19.75)	-145.29 (-183.4)
N_X_MBTE_3B	N-Q-MNSP1 Import	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	211 (17.58)	-22.88 (-37.8)
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	185 (15.42)	-1010.89 (-1098.15)
N^^Q_NIL_B1	NSW1-QLD1 Export	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	151 (12.58)	288.58 (476.29)

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.

Non-real-time constraint automation was not used.

2.5.1 Further Investigation

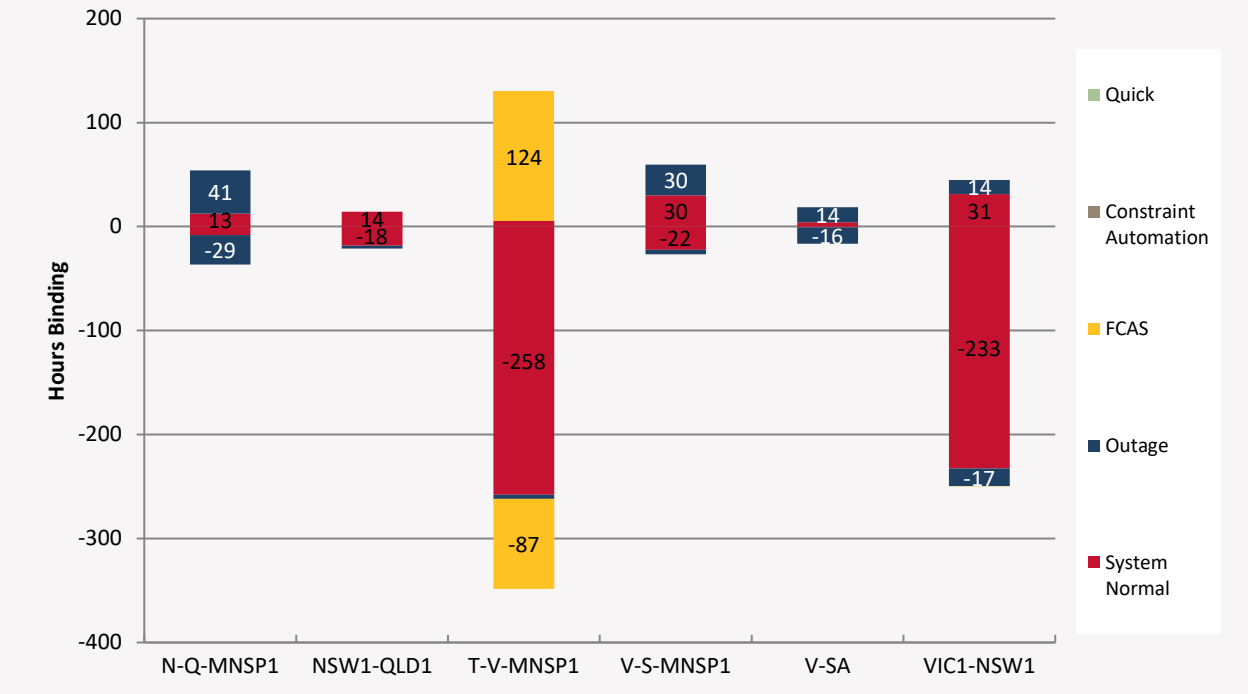
Non-real-time constraint automation was not used.

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.

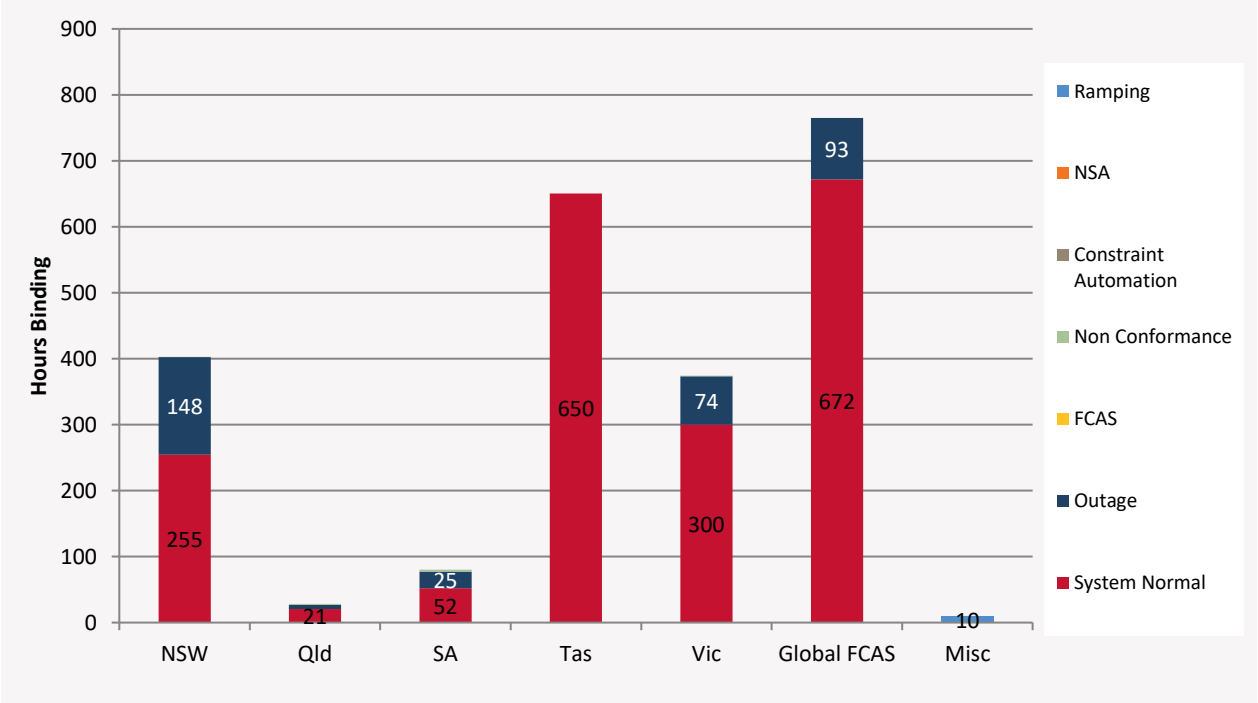
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

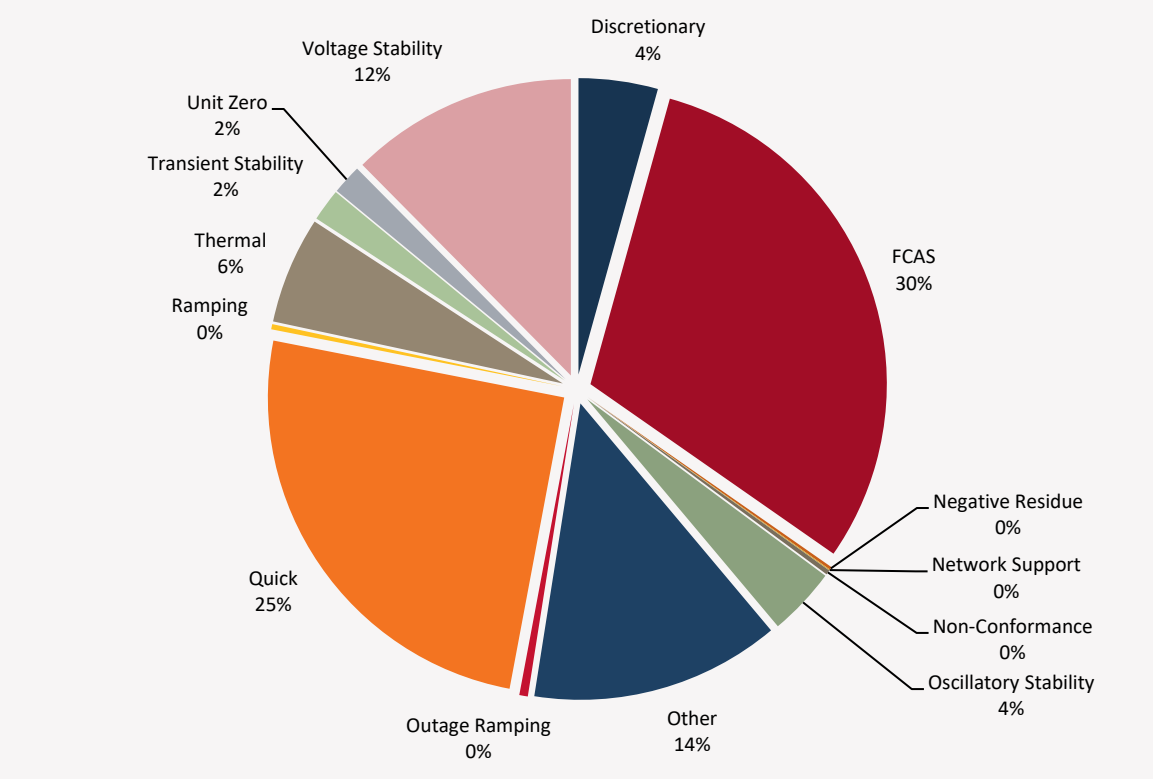
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

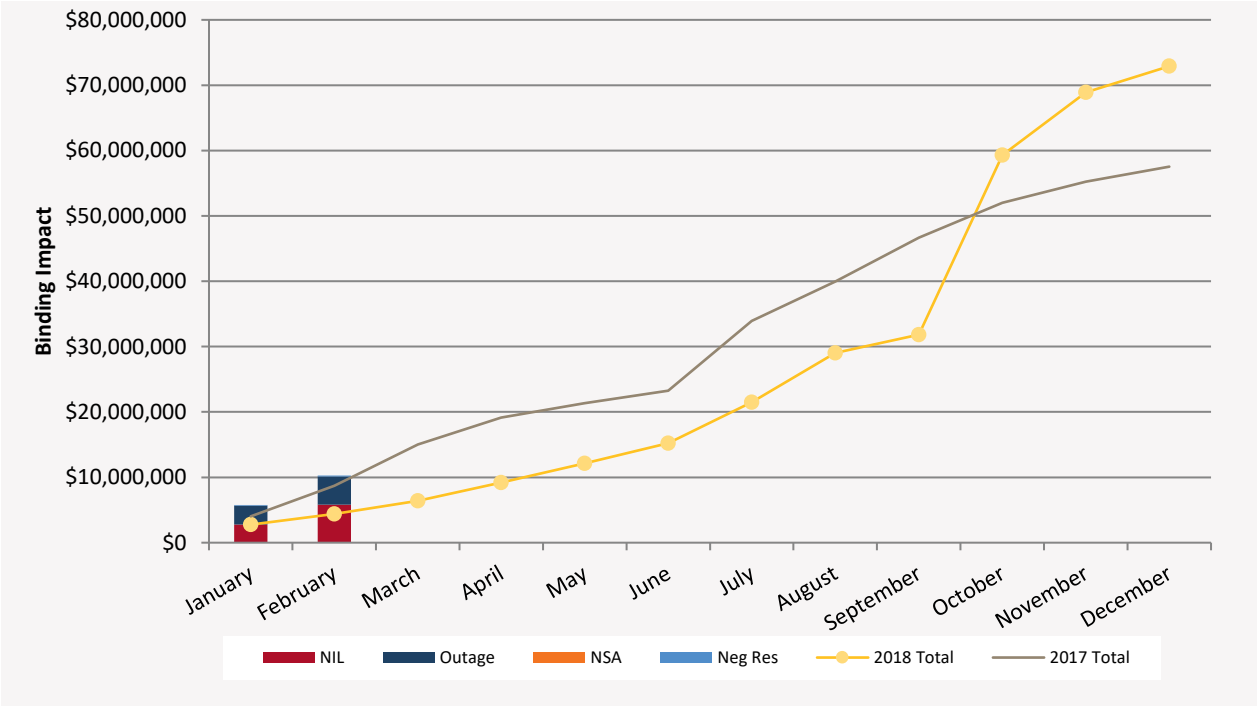
Figure 3 Binding by limit type



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 Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	16	1,584% (84.98)	189% (29.94)
V>SMLARHO1	Out = Ararat to Crowlands or Crowlands to Horsham 220kV line, avoid O/L or voltage collapse on Buronga to Balranald to Darlington Point (X5) line for trip of Bendigo to Kerang 220kV line	12	1,354% (85.11)	390% (49.15)
V::N_HORC_V2	Out = Horsham to Red Cliffs 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	22	449% (179.08)	57.88% (75.57)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	692	447% (261.13)	14.09% (33.01)
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]	3	346% (155.48)	174% (88.37)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_SMF2_V2	Out = South Morang F2 500/330kV txfmr, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	8	132.78% (152.34)	75.19% (96.92)
V>SMLARHO4	Out = Ararat to Crowlands or Crowlands to Horsham 220kV line, avoid O/L Buronga to Redcliffs (0X1) line for trip of Bendigo to Kerang 220kV line	8	127.83% (43.55)	60.78% (19.75)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	17	115.94% (37.1)	41.9% (12.94)
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.	3	98.33% (99.95)	98.33% (99.95)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	554	92.71% (680)	43.09% (177.88)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^SML_HORC_3, V::N_HORC_V2, 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 analogue 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.

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^^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.

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 2019.

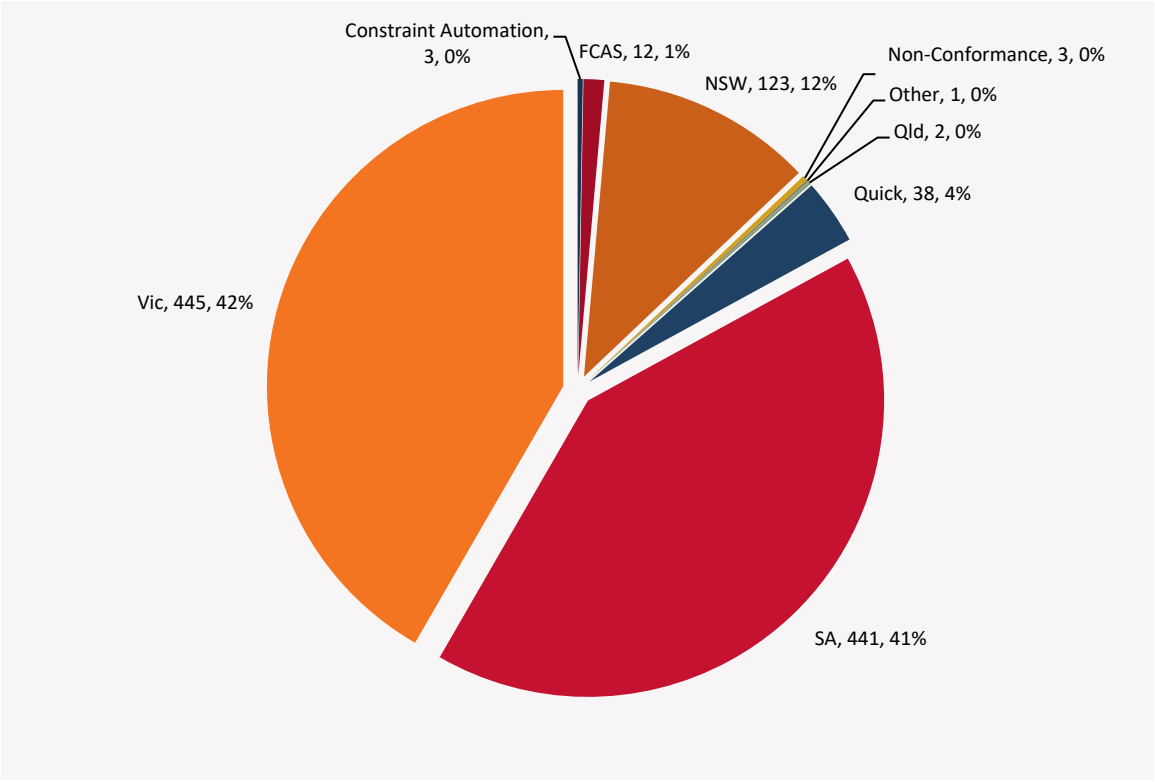
Table 7 Generator and transmission changes

Project	Date	Region	Notes
Tailem Bend Solar Farm	5 February 2019	SA	New Generator
Lilyvale Solar Farm	6 February 2019	QLD	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]

Figure 5 Constraint equation changes



[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

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