AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

March 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 March 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	2487 (207.25)	19/12/2018
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	1875 (156.25)	20/12/2016
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	832 (69.33)	7/12/2018
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	688 (57.33)	13/12/2018
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	581 (48.41)	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	499 (41.58)	7/12/2018
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	427 (35.58)	13/11/2018
Q::N_NIL_AR_2L-G	Out=Nil, limit Qld to NSW on QNI to avoid transient instability for a 2L-G fault at Armidale	407 (33.91)	15/01/2018

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	305 (25.41)	11/01/2019
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.	301 (25.08)	5/12/2018

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_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	545,110	7/12/2018
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	462,175	13/11/2018
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	415,221	19/12/2018
T>T_NIL_110_1	Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback	337,833	11/01/2019
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.	305,433	5/12/2018
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	283,200	4/05/2018
S>>PATW_BWPA_TPRS	Out= Para-Templers West 275kV line, avoid O/L Templers-Roseworthy 132kV line on trip of Blyth West-Munno Para 275kV line, Feedback	196,525	7/03/2019
T_MRWF_QLIM_4	Out = NIL, limit Musselroe Wind Farm to 45 MW if 1 Syncon online only. Swamped if 0 or 2 syncons online	186,334	29/04/2015

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_GANWR_SF_BAT_50	Out = Nil, limit total output of Gannawarra Solar Farm and Battery (Gen component) to 50 MW to prevent overload on Gannawarra txfmr	172,249	24/01/2019
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	156,609	7/12/2018

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 Error! Reference source not found..

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.	14 (1.16)	4/05/2018
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	13 (1.08)	22/03/2017
S>LFTI_PPPW_NOTI4	Out= Torrens Island-Lefevre 275kV line (with TIPS 66kV East and West buses tied, with all 66kV feeders in western 66kV network I/S), avoid O/L New Osborne-TIPS #4 66kV line, on trip of Pelican Point-Parafield Gardens West 275kV line, Feedback	6 (0.5)	18/03/2019
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	4 (0.33)	21/12/2018
S>LFTI_PPPW_LFTX5	Out= Torrens Island-Lefevre 275kV line (with TIPS 66kV East and West buses tied, with all 66kV feeders in western 66kV network I/S), avoid O/L LeFevre 275/132kV TX5 on trip of Pelican Point-Parafield Gardens West 275kV line, Feedback	4 (0.33)	18/03/2019
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 (0.25)	11/01/2019
NSA_Q_BARCALDN	Network Support Agreement for Barcaldine GT to meet local islanded demand for the planned outage of 7153 T71 Clermont to H15 Lilyvale or 7154 T72 Barcaldine to T71 Clermont 132kV line	3 (0.25)	6/05/2015
NSA_V_BDL01_20	Bairnsdale Unit 1 >= 20 MW for Network Support Agreement	2 (0.16)	21/08/2013
NSA_V_BDL02_20	Bairnsdale Unit 2 >= 20 MW for Network Support Agreement	2 (0.16)	21/08/2013
Q>NIL_BI_CAGS_CALV_O	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV split between T022 Callide A and H015 Lilyvale.	2 (0.16)	11/01/2019

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_T_AUFLS2_R6	Constraint equation violated for 14 non-consecutive DIs. Max violation of 76 MW occurred on 25/03/2019 at 1815hrs. Constraint equation violated due to Tasmania raise 6 second service availability being less than the requirement.
T>T_BUSH1_220	Constraint equation violated for 13 DIs, 11 of which were consecutive. Max violation of 6.87 MW occurred on 27/03/2019 at 0720hrs. Constraint equation violated due to Devils Gate hydro unit being unavailable.
S>LFTI_PPPW_NOTI4	Constraint equation violated for 6 non-consecutive DIs. Max violation of 11.77 MW occurred on 18/03/2019 at 1240hrs. Constraint equation violated due to Osbourne gas turbine being limited by its ramp-down rate while Quarantine units 2, 3 and 4 being limited by their start-up profile.
NSA_V_NPSD_100	Constraint equation violated for 4 DIs. Max violation of 61.19 MW occurred on 30/03/2019 at 2335hrs. Constraint equation violated due to Newport unit being limited by its ramp-up rate.
S>LFTI_PPPW_LFTX5	Constraint equation violated for 4 DIs. Max violation of 15.85 MW occurred on 18/03/2019 at 0910hrs. Constraint equation violated due to Pelican Point units being trapped in their Frequency Control Ancillary Services (FCAS) trapezium.
S>NIL_HUWT_STBG2	Constraint equation violated for 3 DIs. Max violation of 18.67 MW occurred on 21/03/2019 at 2125hrs. Constraint equation violated due to Snowtown wind farm being limited by its ramp-down rate.
NSA_Q_BARCALDN	Constraint equation violated for 3 DIs on 15/03/2019 from 1925hrs to 1935hrs with a violation degree of 15.89 MW for each DI. Constraint equation violated due to Barcaldine unit being limited by its start-up profile.
NSA_V_BDL01_20	Constraint equation violated for 2 DIs on 11/03/2019 from 1505hrs to 1510hrs with a violation degree of 20 MW for each DI. Constraint equation violated due to unexpected trip of the Bairnsdale unit 1. A new bid for the Bairnsdale unit 2 was submitted after the trip.
NSA_V_BDL02_20	Constraint equation violated for 2 DIs on 11/03/2019 from 1535hrs to 1540hrs with a violation degree of 20 MW for each DI. Constraint equation violated due to Bairnsdale unit 2 being limited by its start-up profile.
Q>NIL_BI_CAGS_CALV_O	Constraint equation violated for 2 DIs. Max violation of 12.49 MW occurred on 28/03/2019 at 1900hrs. Constraint equation violated due to Gladstone units 3 and 4 being trapped in their Frequency Control Ancillary Services (FCAS) trapeziums.

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	2486 (207.17)	-210.88 (-960.21)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	1455 (121.25)	-379.95 (-478.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
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	1172 (97.67)	-267.51 (-477.99)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	801 (66.75)	-115.62 (478.0)
V^SML_HORC_3	V-S-MNSP1 Export	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	581 (48.42)	-22.44 (71.3)
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	370 (30.83)	-1010.09 (-1129.04)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	365 (30.42)	-176.38 (478.0)
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	339 (28.25)	-358.2 (-477.99)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	240 (20.0)	-45.52 (478.0)
S>>PATW_BWPA_TPRS	V-S-MNSP1 Export	Out= Para-Templers West 275kV line, avoid O/L Templers-Roseworthy 132kV line on trip of Blyth West-Munno Para 275kV line, Feedback	225 (18.75)	-132.86 (-2.86)

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

Table 6 Non-Real-Time Constraint Automation usage

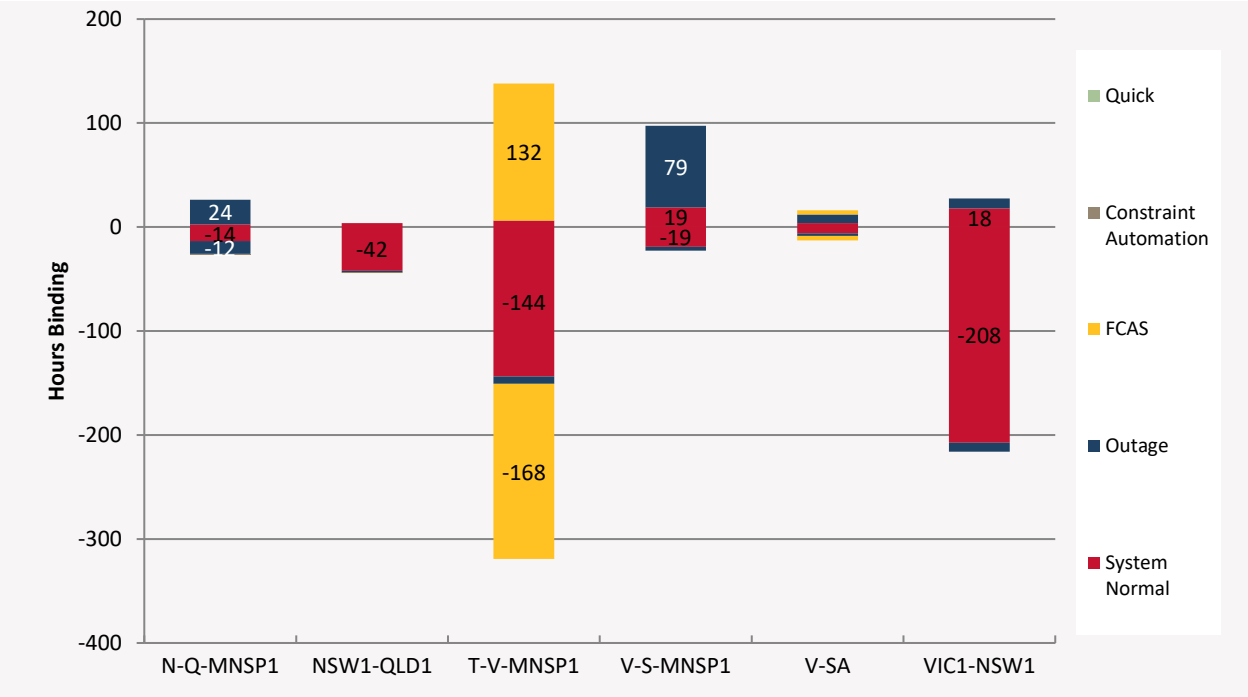
Constraint Set ID	Date Time	Description
CA_SPS_4B902E2A	05/03/2019 08:50 to 05/03/2019 11:00	Automated constraint equation was created for the planned outage of the 9U6 Mullumbimby to Lismore 132kV line, avoid overload the remaining 9U7 Mullumbimby to Lismore 132kV line, for trip of the 9G5 Mullumbimby to Ewingsdale 132kV line. Existing constraint equation N>N_LSDU_9U6_3 has been updated.
CA_MQS_4BA18A48	18/03/2019 12:40 to 18/03/2019 12:40	Automated constraint equation was created for the planned outage of Torrens Island to Lefevre 275kV line (with Torrens Island 66kV East and West buses tied, with all 66kV feeders in western 66kV network in service), avoid overload New Osborne to Torrens Island No. 4 66kV line, for trip of Pelican Point to Parafield Gardens West 275kV line. New constraint equation S>LFTI_PPPW_NOTI4 has been created.

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.

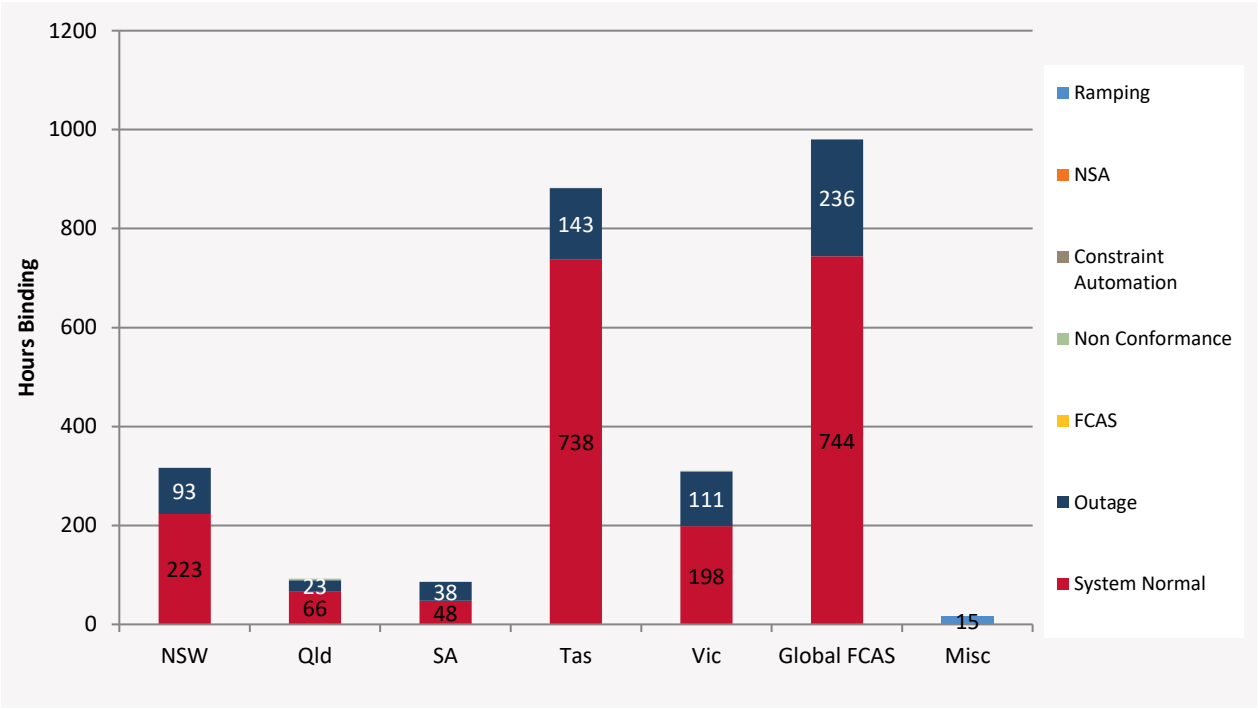
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

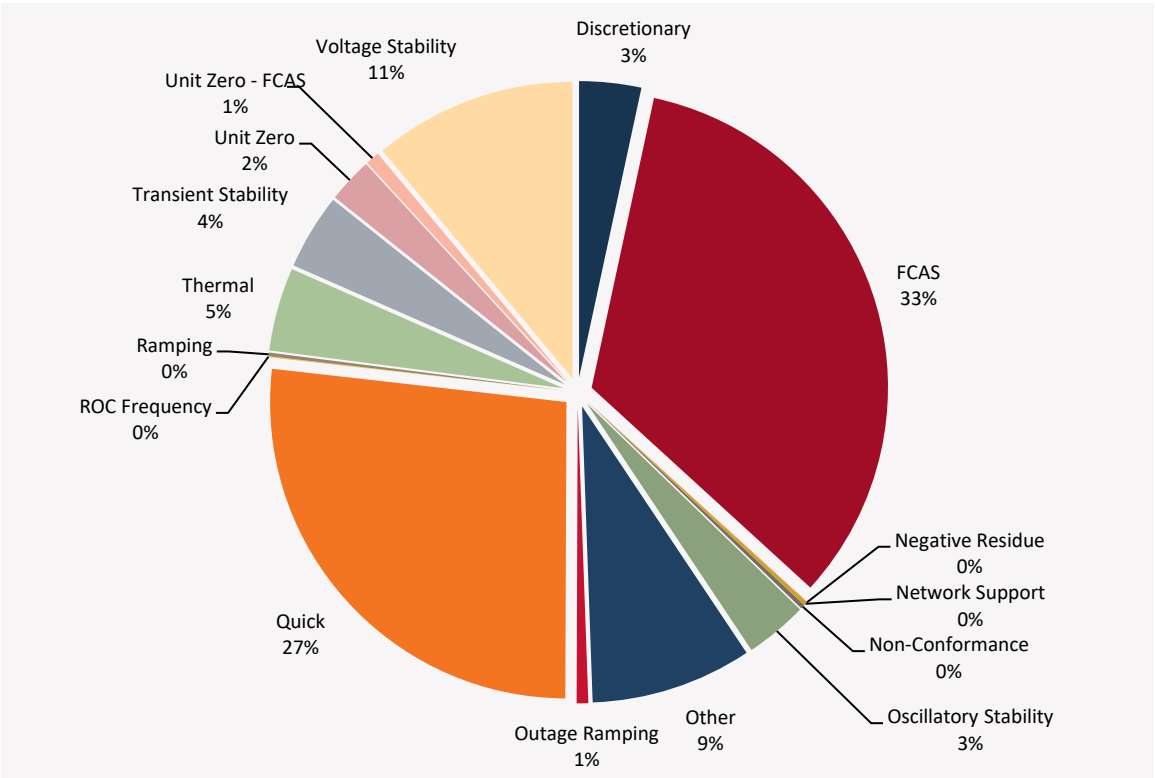
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

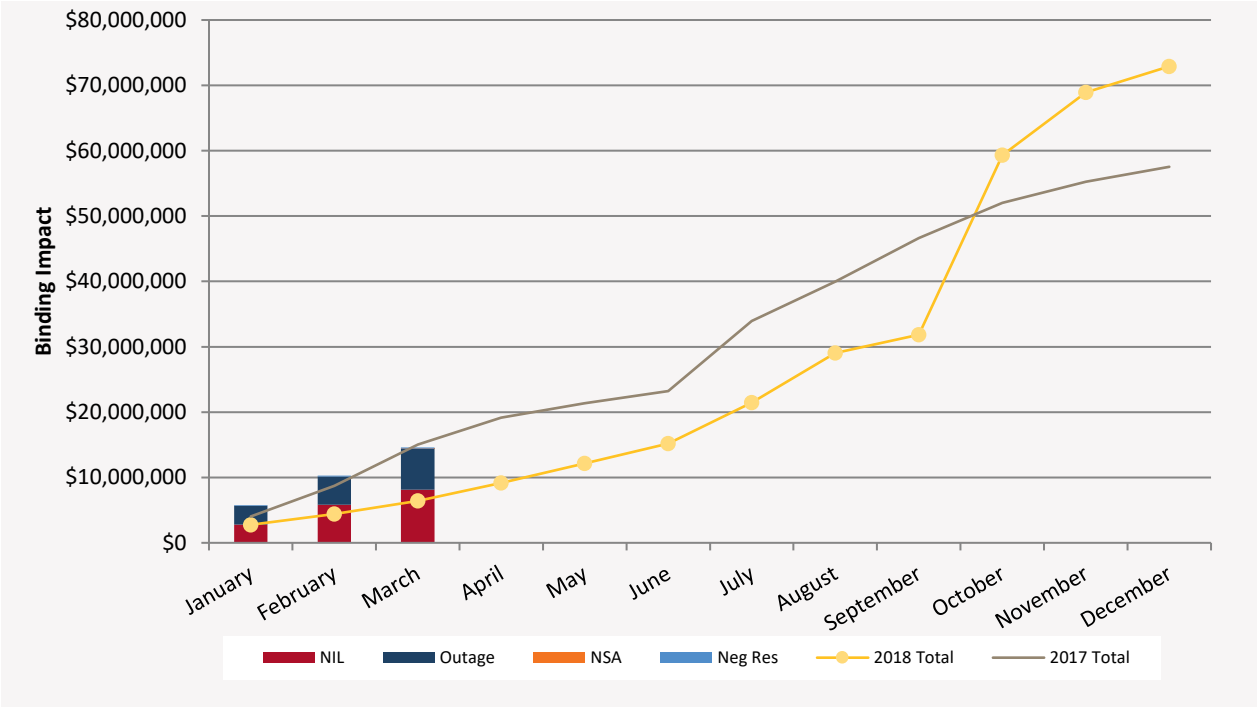
Figure 3 Binding by limit type



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 7 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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	8	4,500,000 % (45.)	2,250,050% (45.)
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.	15	1,555% (118.3)	152% (56.33)

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	93	868% (97.98)	108.82% (22.02)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	377	392% (369.79)	29.82% (69.15)
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]	9	327% (127.68)	123.21% (67.84)
T::T_NIL_2	Out = NIL, prevent transient instability for fault and trip of a Farrell to Sheffield line, Tamar Valley CCGT out of service, Basslink importing	54	115.35% (307.49)	32.35% (117.28)
S>SE6161_SETX2_SGBL	Out= South East 132kV CB6161, avoid O/L Snuggery-Blanche 132kV line on trip of South East 132/275 TX2 (this offloads Mayura-South East T 132kV line), Feedback	7	110.48% (35.68)	57.23% (17.82)
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.	8	98.33% (99.95)	92.23% (99.95)
Q>NIL_MUTE_758	Out= Nil, ECS for managing 758 H4 Mudgeeraba to T174 Terranora 110kV line, Summer and Winter ECS ratings selected by SCADA status.	4	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	464	94.31% (689)	38.91% (173.52)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V_KARSF_45_21INV, V::N_HWSM_V1, V^SML_HORC_3, S>NIL_HUWT_STBG2, S>SE6161_SETX2_SGBL, T::T_NIL_2: 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.

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 March 2019.

Table 8 Generator and transmission changes

Project	Date	Region	Notes
Oakey 1 Solar Farm	12 March 2019	QLD	New Generator
Lincoln Gap Wind Farm	19 March 2019	SA	New Generator
Murra Warra Wind Farm Stage 1	19 March 2019	VIC	New Generator

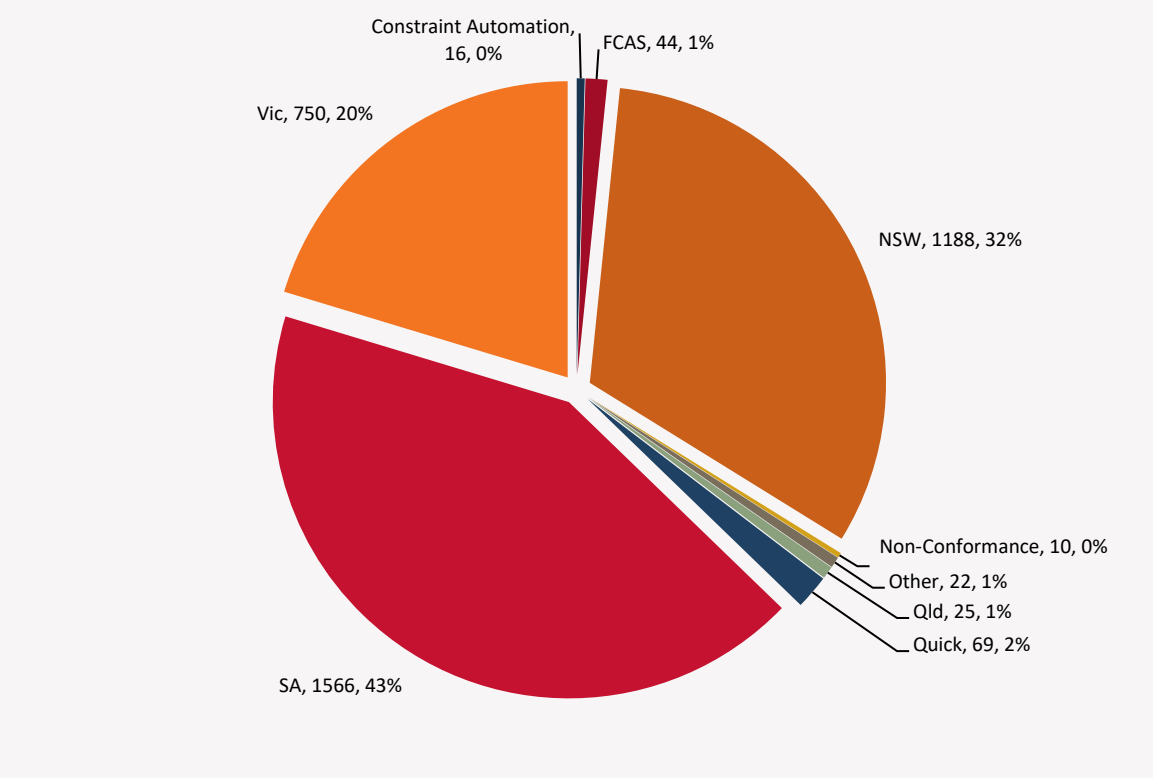
3.1 Constraint Equation Changes

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