AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

July 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 July 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	3354 (279.5)	13/08/2019
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.	1806 (150.5)	23/07/2019
V_MACARTHUR_ZERO	Macarthur upper limit of 0 MW	1591 (132.58)	21/08/2013
Q>CPWO_B_CAGS_CALV_C	Out= 813+815 or 814+816,H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104 and 7105 (T022 Callide A to T152 Gladstone South)132 kV lines close with 132 kV intact between T022 Callide A and H015 Lilyvale, Feedback	807 (67.25)	26/07/2019
Q_CLST_STRGTH_MEWF	Out = 855 or 8873 or 8874 or 856 or 8831, limit Mt Emerald WF to 50% capacity (26 turbines) if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=3 + Gladstone >=3 + (Stan+Cal+Glad >=10) + Haughton >0 + Sun Metals >0. Zero otherwise.	584 (48.66)	19/07/2019
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	556 (46.33)	19/07/2019
SV_100	SA to Victoria on VicSA upper transfer limit of 100 MW	397 (33.08)	8/01/2014

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V_MURRAWRWF_FLT_25	Limit Murra Warra Wind Farm upper limit to 25 MW to manage system stability on the next contingency due to voltage oscillation	378 (31.5)	19/07/2019
S_DVRB_270	Out = DV-BL 275kV line Or MK-RB 275kV line O/S, discretionary upper limit for North Brown Hill WF + Bluff WF + Willogolechie WF + Hallet Hill WF (i.e. generation + load component) <= 270 MW	375 (31.25)	13/04/2018
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	359 (29.91)	18/06/2019

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
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.	1,991,332	23/07/2019
Q_CLST_STRGTH_MEWF	Out = 855 or 8873 or 8874 or 856 or 8831, limit Mt Emerald WF to 50% capacity (26 turbines) if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=3 + Gladstone >=3 + (Stan+Cal+Glad >=10) + Haughton >0 + Sun Metals >0. Zero otherwise.	600,586	19/07/2019
Q>CPWO_B_CAGS_CALV_C	Out= 813+815 or 814+816,H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104 and 7105 (T022 Callide A to T152 Gladstone South)132 kV lines close with 132 kV intact between T022 Callide A and H015 Lilyvale, Feedback	412,535	26/07/2019
V_MURRAWRWF_FLT_25	Limit Murra Warra Wind Farm upper limit to 25 MW to manage system stability on the next contingency due to voltage oscillation	408,789	19/07/2019
S_HALWF_0	Discretionary upper limit for Hallett Wind Farm generation of 0 MW	334,327	7/08/2018
V_MACARTHUR_ZERO	Macarthur upper limit of 0 MW	329,572	21/08/2013

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
S_DVRB_270	Out = DV-BL 275kV line Or MK-RB 275kV line O/S, discretionary upper limit for North Brown Hill WF + Bluff WF + Willogolechie WF + Hallet Hill WF (i.e. generation + load component) <= 270 MW	284,119	13/04/2018
Q_CLST_STRGTH_HAUSF	Out = 855 or 8873 or 8874 or 856 or 8831, limit Haughton SF to 50% capacity (40 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=3 + Gladstone >=3 + (Stan+Cal+Glad >=10). Zero otherwise.	236,782	19/07/2019
Q_STR_43249_SMSF_38	Limit Sun Metals SF to 50% capacity (38 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=4 + (Stan+Cal+Glad >=9). Zero otherwise.	229,170	8/07/2019
Q_STR_43249_HASF_40	Limit Haughton SF to 50% capacity (40 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=4 + (Stan+Cal+Glad >=9). Zero otherwise.	227,234	8/07/2019

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

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
Q_CLST_STRGTH_MEWF	Out = 855 or 8873 or 8874 or 856 or 8831, limit Mt Emerald WF to 50% capacity (26 turbines) if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=3 + Gladstone >=3 + (Stan+Cal+Glad >=10) + Haughton >0 + Sun Metals >0. Zero otherwise.	102 (8.5)	19/07/2019
Q_STBS_STRGTH_MEWF	Out = 856+822, limit Mt Emerald WF to 50% capacity (26 turbines) if Kareeya >=2 and Invicta is ON and Stanwell >=3 + Callide >=3 + Gladstone >=3 and Stan+Cal+Glad >=10 + Haughton >0 + Sun Metals >0. Zero otherwise.	102 (8.5)	19/07/2019
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	12 (1.0)	6/05/2015
NSA_V_BDL01_20	Bairnsdale Unit 1 >= 20 MW for Network Support Agreement	4 (0.33)	21/08/2013
N_COLMBSF_60_INV	Limit Coleambally Solar Farm upper limit to 0 MW if number of inverter available exceed 60. Dispatch only. swamped out if Inverters are within the limit.	1 (0.08)	19/07/2019
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 able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	1 (0.08)	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 able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	1 (0.08)	12/04/2016

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
Q>X_CPWO_BI_INTACT	Out= 813+815 or 814+816,H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104 and 7105 (T022 Callide A to T152 Gladstone South) 132 kV lines open with 132 kV intact between T022 Callide A and H015 Lilyvale, Feedback	1 (0.08)	26/07/2019
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 able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	1 (0.08)	12/04/2016
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	1 (0.08)	30/04/2018

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
Q_CLST_STRGTH_MEWF	Constraint equation violated for 102 consecutive DIs with a violation degree of 10,000 MW for each DI. The logic in the constraint equation should have set the RHS to a value of zero and instead set to -10,000 and so violated. The constraint equations were fixed on the day. There was no power system security issue as the generators were (correctly) getting targets of zero.
Q_STBS_STRGTH_MEWF	Constraint equation violated for 102 consecutive DIs with a violation degree of 10,000 MW for each DI. Constraint equation violated due to the same reason as Q_CLST_STRGTH_MEWF.
NSA_Q_BARCALDN	Constraint equation violated for 12 non-consecutive DIs. Max violation of 15 MW occurred on 24/07/2019 at 1935hrs. Constraint equation violated due to Barcaldine GT unit being unavailable.
NSA_V_BDL01_20	Constraint equation violated for 4 DIs on 13/07/2019 from 0705hrs to 0720hrs 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_COLMBSF_60_INV	Constraint equation violated for 1 DI on 02/07/2019 at 1335hrs with a violation degree of 43.4 MW. Constraint equation violated due to inaccurate SCADA information received.
F_T++NIL_WF_TG_R5	Constraint equation violated for 1 DI on 02/07/2019 at 1235hrs with a violation degree of 21.79 MW. Constraint equation violated due to Tasmania raise 5 minutes service availability being less than the requirement.
F_T++NIL_WF_TG_R6	Constraint equation violated for 1 DI on 02/07/2019 at 1235hrs with a violation degree of 15.72 MW. Constraint equation violated due to Tasmania raise 6 seconds service availability being less than the requirement.
Q>X_CPWO_BI_INTACT	Constraint equation violated for 1 DI on 20/07/2019 at 0805hrs with a violation degree of 9.04 MW. Constraint equation violated due to Gladstone units 1, 3, 4 and 6 being limited by their ramp-down rates.
F_T++NIL_WF_TG_R60	Constraint equation violated for 1 DI on 02/07/2019 at 1235hrs with a violation degree of 7.36 MW. Constraint equation violated due to Tasmania raise 60 seconds service availability being less than the requirement.
F_T_NIL_MINP_R6	Constraint equation violated for 1 DI on 02/07/2019 at 1235hrs with a violation degree of 7.07 MW. Constraint equation violated due to the same reason as F_T++NIL_WF_TG_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	3354 (279.5)	-171.76 (-783.78)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1457 (121.42)	325.46 (478.0)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	709 (59.08)	316.84 (478.0)
F_S++HYSE_L6_1	V-SA Import	Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 6 sec Requirement for risk of islanding, segment1	580 (48.33)	-103.88 (-179.37)
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	531 (44.25)	108.44 (-447.19)
F_S++HYSE_L60	V-SA Import	Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 60 sec Requirement for risk of islanding	483 (40.25)	-112.11 (-173.22)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	459 (38.25)	255.89 (478.0)
SV_100	V-SA Import	SA to Victoria on VicSA upper transfer limit of 100 MW	397 (33.08)	-100.0 (-100.0)
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	359 (29.92)	-896.15 (-1015.82)
N_X_MBTE_3B	N-Q-MNSP1 Import	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	344 (28.67)	-17.77 (-36.7)

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

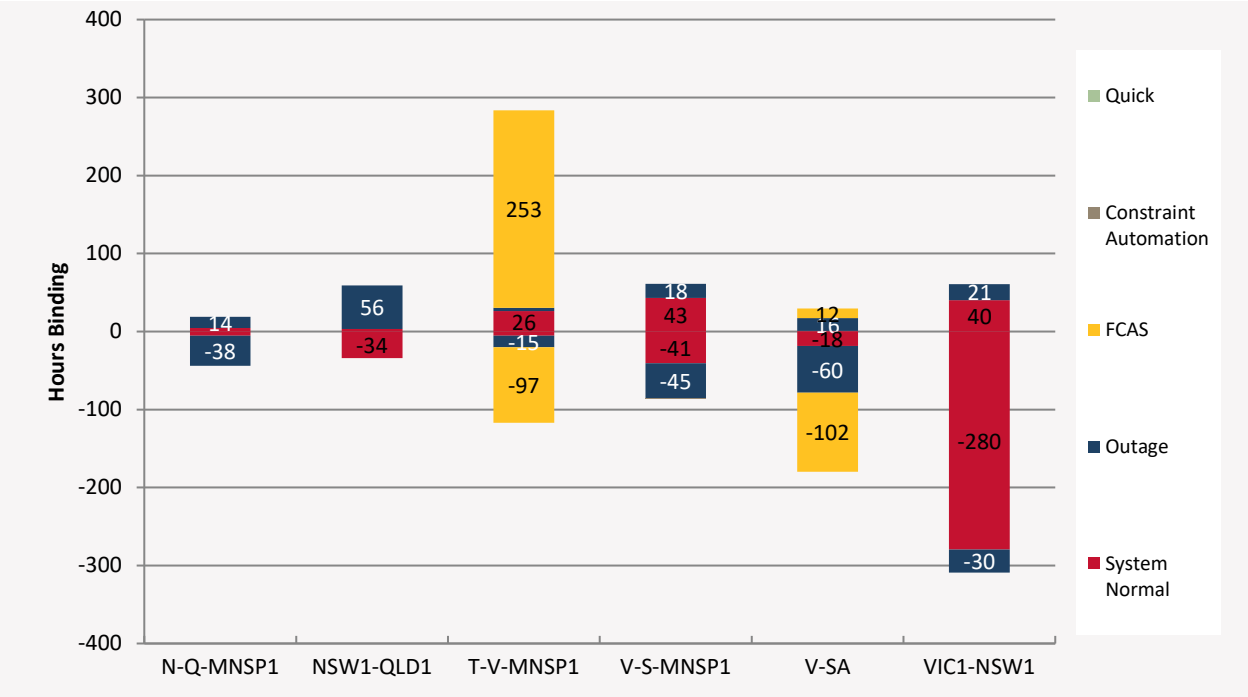
Constraint Set ID	Date Time	Description
CA_MQS_4C47A69C	22/07/2019 12:15 to 22/07/2019 12:55	Automated constraint equations were created to manage thermal overload on Waubra to Ballarat 220kV line for loss of Buronga to Balranald to Darlington Point 220kV line during prior outages of Kerang to Wemen 220kV line. Constraint equation V>>V_KGWT_3 was created at a later stage to manage the thermal overload above.

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.

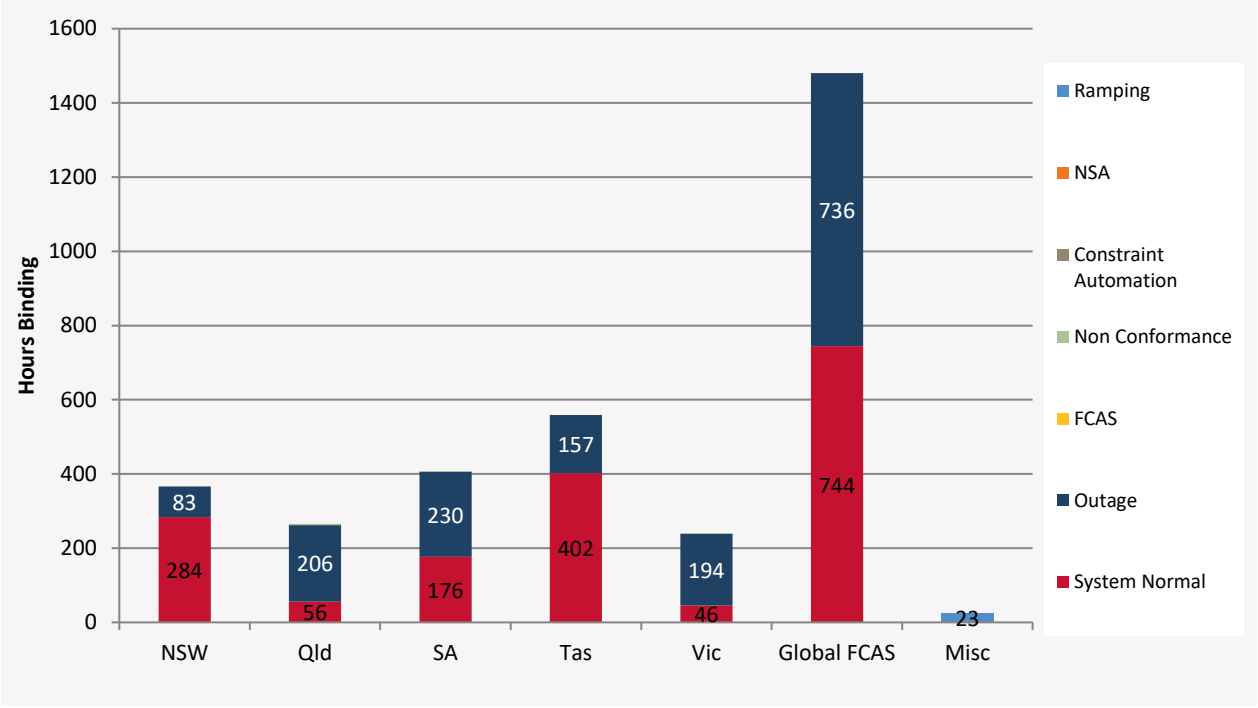
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

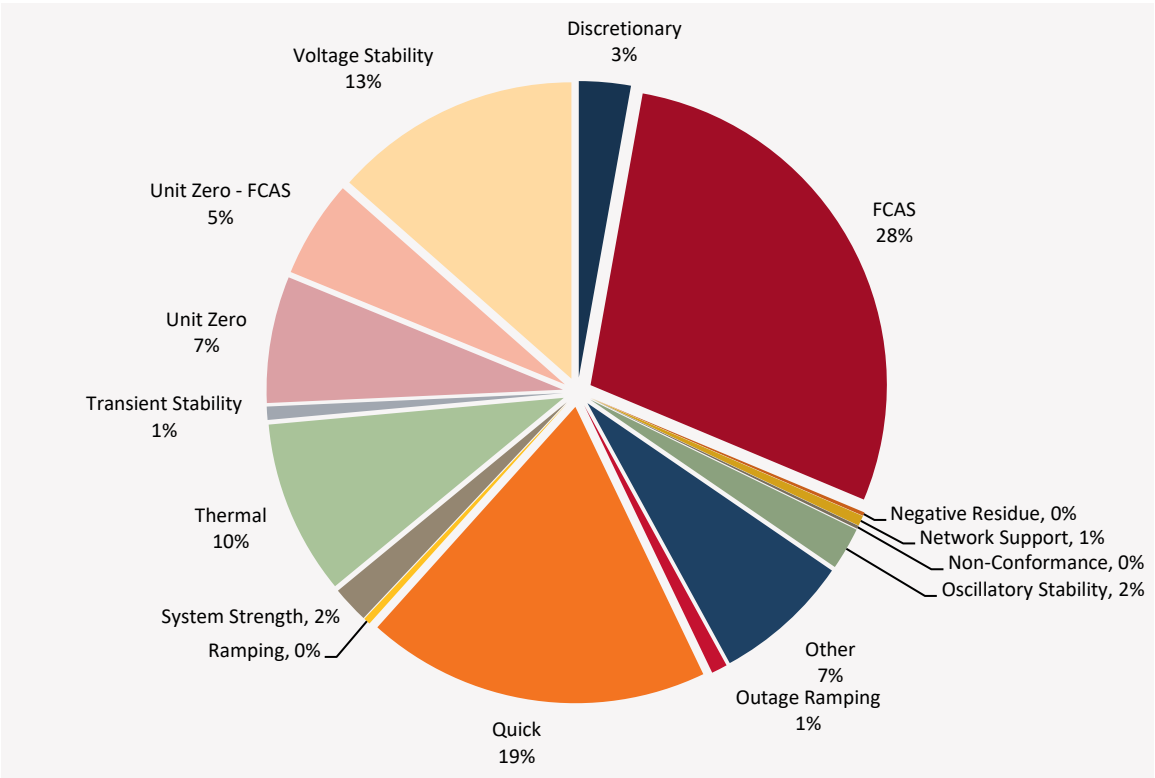
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

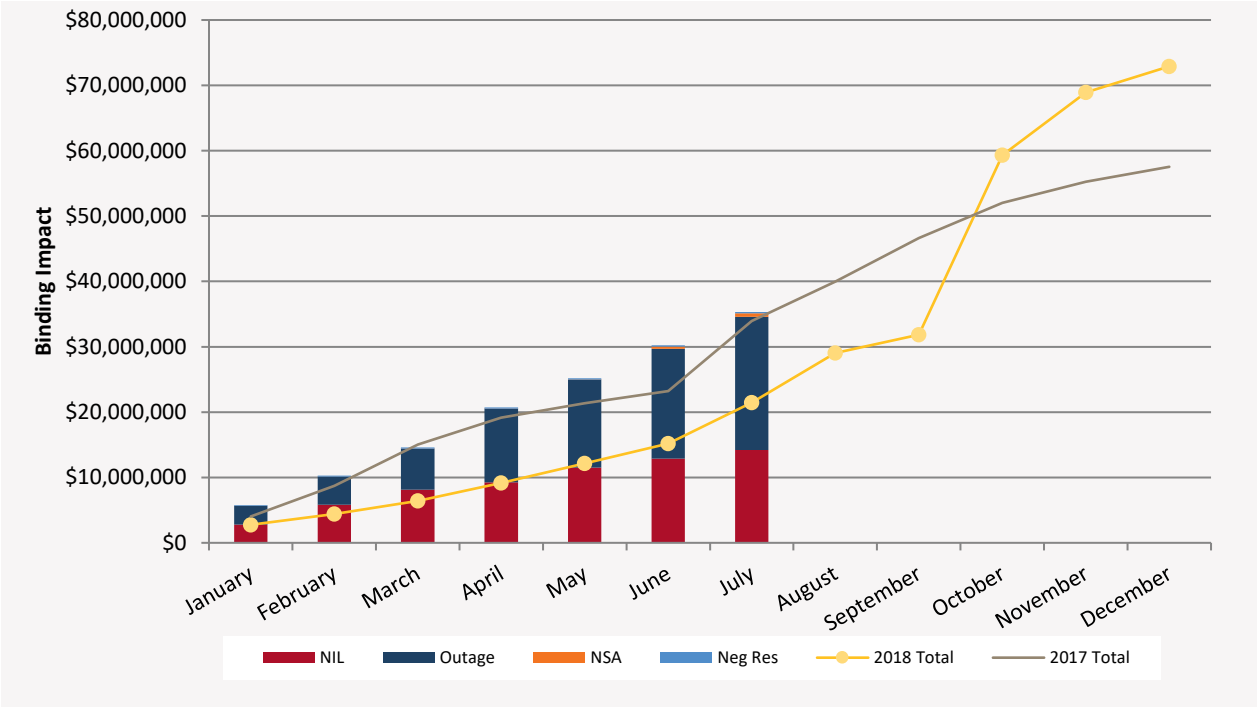
Figure 3 Binding by limit type



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
Q_STR_43249_MEWF_26	Limit Mt Emerald WF to 50% capacity (26 turbines) if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=4 + (Stan+Cal+Glad >=9) + Haughton >0 + Sun Metals >0. Zero otherwise.	5	90,000,000% (90.)	90,000,000% (90.)
Q_STBS_STRGTH_MEWF	Out = 856+822, limit Mt Emerald WF to 50% capacity (26 turbines) if Kareeya >=2 and Invicta is ON and Stanwell >=3 + Callide >=3 + Gladstone >=3 and Stan+Cal+Glad >=10 + Haughton >0 + Sun Metals >0. Zero otherwise.	8	90,000,000% (90.)	33,750,063% (90.)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
Q_STBS_STRGTH_SMSF	Out = 856+822, limit Sun Metals SF to 50% of max capacity (38 inverters) if Kareeya >=2 and Invicta is ON and Stanwell >=3 + Callide >=3 + Gladstone >=3 and Stan+Cal+Glad >=10. Zero otherwise.	10	61,000,000% (61.)	18,300,070% (61.)
Q_STR_43249_SMSF_38	Limit Sun Metals SF to 50% capacity (38 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=4 + (Stan+Cal+Glad >=9). Zero otherwise.	6	61,000,000% (61.)	61,000,000% (61.)
Q_STR_43249_HASF_40	Limit Haughton SF to 50% capacity (40 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=4 + (Stan+Cal+Glad >=9). Zero otherwise.	6	55,000,000% (55.)	55,000,000% (55.)
Q_STBS_STRGTH_HAUSF	Out = 856+822, limit Haughton SF to 50% of max capacity (40 inverters) if Kareeya >=2 and Invicta is ON and Stanwell >=3 + Callide >=3 + Gladstone >=3 and Stan+Cal+Glad >=10. Zero otherwise.	8	55,000,000% (55.)	20,625,063% (55.)
N^^V_DDSM1	Out = Dederang to South Morang 330 kV line, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink or the parallel Dederang to South Morang 330kV line	52	8,551% (167.98)	465% (54.93)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	647	3,004% (801)	92.67% (137.26)
V^SML_KGRC_4	Out = Kerang to Wemen or Red Cliffs to Wemen 220kV line sections, or full Kerang to Wemen to Red Cliffs 220kV line, avoid voltage collapse for loss of Horsham to Ararat 220kV line	10	1,571% (77.16)	621% (39.93)
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.	284	896% (9,333)	27.93% (342.84)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N^^V_DDSM1, Q_STR_43249_MEWF_26, Q_STBS_STRGTH_MEWF, Q_STBS_STRGTH_SMSF, Q_STR_43249_SMSF_38, Q_STR_43249_HASF_40, Q_STBS_STRGTH_HAUSF, S_NIL_STRENGTH_1: 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.

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 July 2019.

Table 8 Generator and transmission changes

Project	Date	Region	Notes
Bridgewater to Waddamana 110kV Line	2 July 2019	TAS	Decommissioned Transmission Line
Finley Solar Farm	30 July 2019	NSW	New Generator

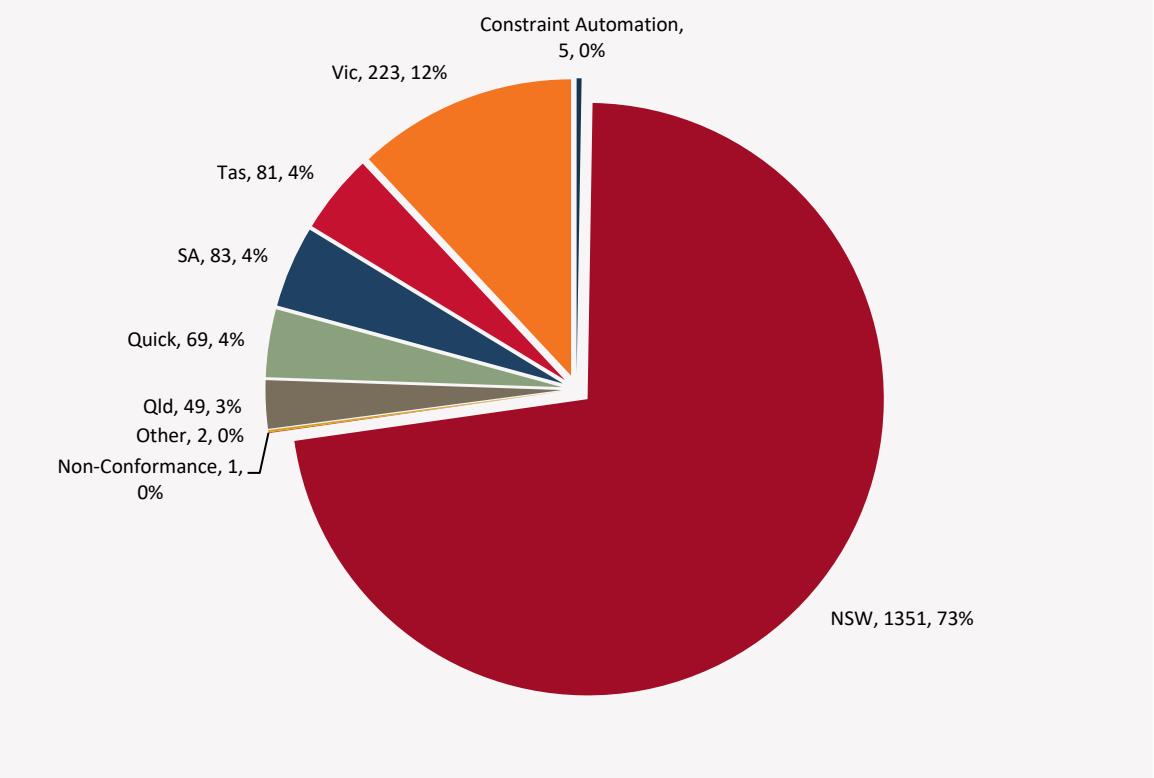
3.1 Constraint Equation Changes

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