AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

October 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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Contents

Tables

Figures

1. Introduction

This report details constraint equation performance and transmission congestion related issues for October 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
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	4667 (388.91)	21/08/2013
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	2529 (210.75)	20/12/2016
Q_CS_1100	Qld Central to Qld South upper transfer limit of 1100MW (discretionary)	2166 (180.5)	29/05/2019
N_MBTE1_B	Out= one Directlink cable, Qld to NSW limit	1263 (105.25)	25/11/2013
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	1252 (104.33)	18/06/2019
V_MACARTHUR_ZERO	Macarthur upper limit of 0 MW	1154 (96.16)	21/08/2013
N_STWF1_ZERO	Silverton wind farm upper limit of 0 MW	1046 (87.16)	6/02/2018
N_BROKENHSF_FLT_26	Limit Broken Hill Solar Farm upper limit to 26 MW to manage post contingent voltage oscillation	951 (79.25)	5/09/2019
N_BROKENH1_ZERO	Broken Hill Solar Farm upper limit of 0 MW	948 (79.0)	13/08/2015

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V_GANWRSF_FLT_25	Limit Gannawarra solar farm upper limit to 25 MW to manage post contingent voltage oscillation	898 (74.83)	4/09/2019

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
Q_CS_1100	Qld Central to Qld South upper transfer limit of 1100MW (discretionary)	2,161,239	29/05/2019
N_STWF1_ZERO	Silverton wind farm upper limit of 0 MW	1,140,126	6/02/2018
N_BROKENH1_ZERO	Broken Hill Solar Farm upper limit of 0 MW	1,041,514	13/08/2015
N_BROKENHSF_FLT_26	Limit Broken Hill Solar Farm upper limit to 26 MW to manage post contingent voltage oscillation	1,029,752	5/09/2019
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/split btw T022 Callide A and H015 Lilyvale, Feedback	610,748	23/09/2019
Q_CS_1850	Qld Central to Qld South upper transfer limit of 1850MW (discretionary)	510,456	29/05/2019
Q_LILYSF1_ZERO	Lilyvale Solar Farm upper limit of 0 MW	498,407	20/08/2018
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.	450,591	16/09/2019
S>>X_CNRB+CB_01	Out= Out= Canowie-Robertstown 275kV line + Associated line CBs 6616 & 6571 at Robertstown O/S), avoid O/L Robertstown 275/132kV TX1 on trip of Robertstown-Para 275kV line, Feedback	401,303	2/10/2019
F_MAIN+NIL_DYN_RREG	Mainland Raise Regulation Requirement, Feedback in Dispatch, increase by 60 MW for each 1s of time error below -1.5s	308,983	23/05/2019

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.

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
N^N-LS_SVC	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; TG formulation only	52 (4.33)	27/08/2018
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	13 (1.08)	12/04/2016
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	13 (1.08)	4/05/2018
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	12 (1.0)	21/12/2018
N>N-96H+96R_TE_1	Out= Coffs Harbour to Koolkhan (96H) and Glen Innes to Tenterfield (96R) 132kV line, avoid O/L Armidale to Koolkhan (966) on trip of Coffs Harbour to Lismore (89), Swamp out when all 3 directlink cable O/S,TG formulation for PD/ST	5 (0.41)	21/08/2013
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	3 (0.25)	12/04/2016
F_S++HYSE_L6_1	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	2 (0.16)	25/11/2015
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	2 (0.16)	21/08/2013
V_VS_LB_CAN_50	Limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement when SA is at risk of separation.	2 (0.16)	16/09/2019
NSA_V_BDL01_20	Bairnsdale Unit 1 >= 20 MW for Network Support Agreement	1 (0.08)	21/08/2013

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
N^N-LS_SVC	Constraint equation violated for 52 non-consecutive DIs. Max violation of 77.86 MW occurred on 08/10/2019 at 1615hrs. Constraint equation violated due to competing requirements with import

Constraint Equation ID (System Normal Bold)	Description
	constraint N_X_MBTE_3B. On 9/10/2019, the constraint equation violated due to bad SCADA at Lismore no 2 Cap
F_T+NIL_WF_TG_R6	Constraint equation violated for 13 non-consecutive DIs. Max violation of 34.37 MW occurred on 25/10/2019 at 0210 hrs. Constraint equation violated due to Tasmania raise 6 second service availability being less than the requirement.
F_T_AUFLS2_R6	Constraint equation violated for 13 non-consecutive DIs. Max violation of 23.2 MW occurred on 23/10/2019 at 1215hrs. Constraint equation violated due to Tasmania raise 6 second service availability being less than the requirement.
NSA_V_NPSD_100	Constraint equation violated for 12 non-consecutive DIs. Max violation of 100 MW occurred on 26/10/2019 at 1225hrs. Constraint equation violated due to Newport generator being limited by its start up profile.
N>N-96H+96R_TE_1	Constraint equation violated for 5 DIs. Max violation of 66.83 MW occurred on 22/10/2019 at 1025hrs. Constraint equation violated due to competing requirement with import constraint QNTE_ROC.
F_T+NIL_MG_R6	Constraint equation violated for 3 DIs on 16/10/2019 at 0710hrs, on 17/10/2019 at 1355hrs and on 23/10/2019 at 1215hrs. Max violation of 11.28 MW occurred on 23/10/2019 at 1215hrs. Constraint equation violated due to Tasmania raise 6 second service availability being less than the requirement.
F_S++HYSE_L6_1	Constraint equation violated for 2 DIs on 05/10/2019 at 1345hrs and 1425hrs Max violation of 30.96 MW occurred on 05/10/2019 at 1425hrs. Constraint equation violated due to competing requirements with export constraint V_VS_LB_CAN_50.
N>N-LSTN_TE_C1	Constraint equation violated for 2 DIs on 08/10/2019 at 1615 hrs and 1620hrs with violations of 28 MW at both DIs. Constraint equation violated due to the same reason as N^N-LS_SVC
V_VS_LB_CAN_50	Constraint equation violated for 2 DIs on 05/10/2019 at 1425hrs and on 29/10/2019 at 1200hrs. Max violation of 6.44 MW occurred on 05/10/2019 at 1425hrs. Constraint equation violated due to Lake Bonney generators being limited by its ramp rate.
NSA_V_BDL01_20	Constraint equation violated for 1 DI on 06/10/2019 at 1605hrs with violation of 20 MW. Constraint equation violated due to Bairnsdale generator being limited by its start up profile.

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)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	4633 (386.08)	0.0 (0.0)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	1941 (161.75)	-396.92 (-463.12)
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	1284 (107.0)	-245.53 (-461.68)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N_MBTE1_B	N-Q-MNSP1 Import	Out= one Directlink cable, Qld to NSW limit	1263 (105.25)	-129.5 (-158.2)
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	1246 (103.83)	-974.14 (-1114.68)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	967 (80.58)	-12.41 (478.0)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	764 (63.67)	7.11 (478.0)
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	695 (57.92)	-93.98 (-185.82)
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	680 (56.67)	-533.42 (-1015.97)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	626 (52.17)	-47.95 (478.0)

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_MQS_4CA64299	02/10/2019 06:35 to 02/10/2019 09:10	To manage overload on Waterloo-Hummucks on trip of Bungama-Brinkworth during multiple outage of Bungama Transformer + Robertstown - Para 275 kV line in South Australia region.

2.5.1 Further Investigation

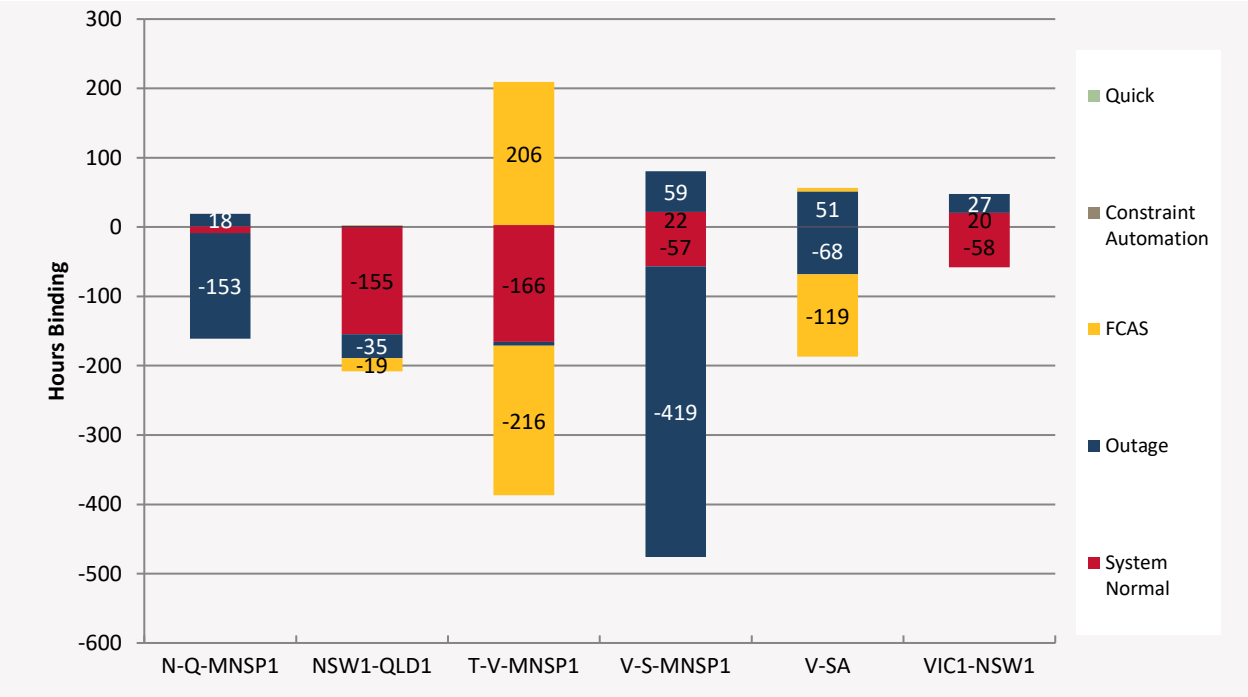
CA_MQS_4CA64299: Constraint has been added to manage the multiple outage of Bungama Transformer + Robertstown - Para 275 kV line

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.

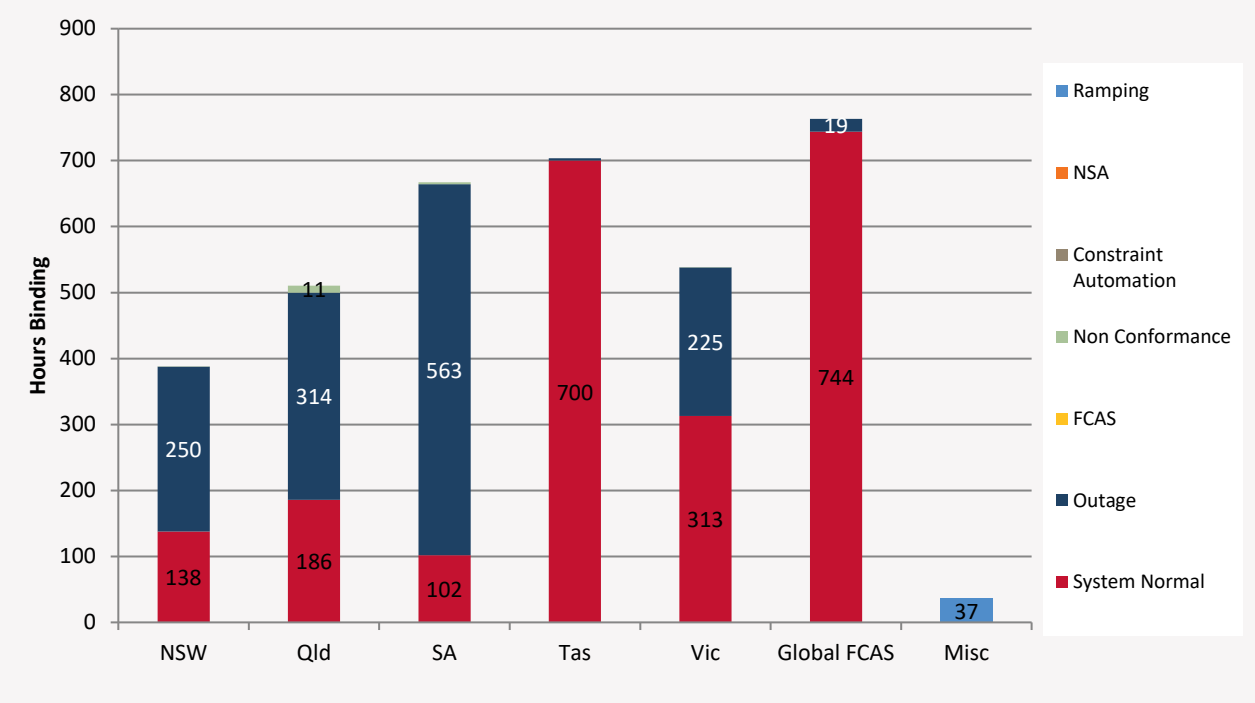
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

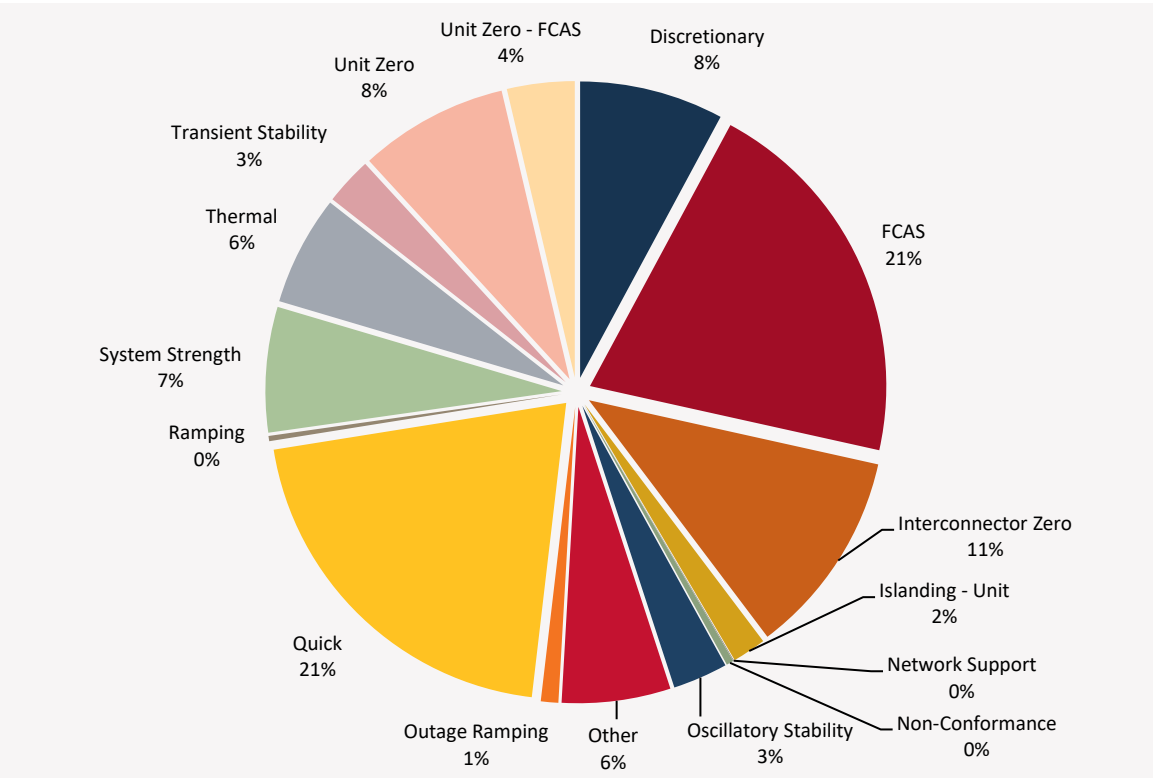
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

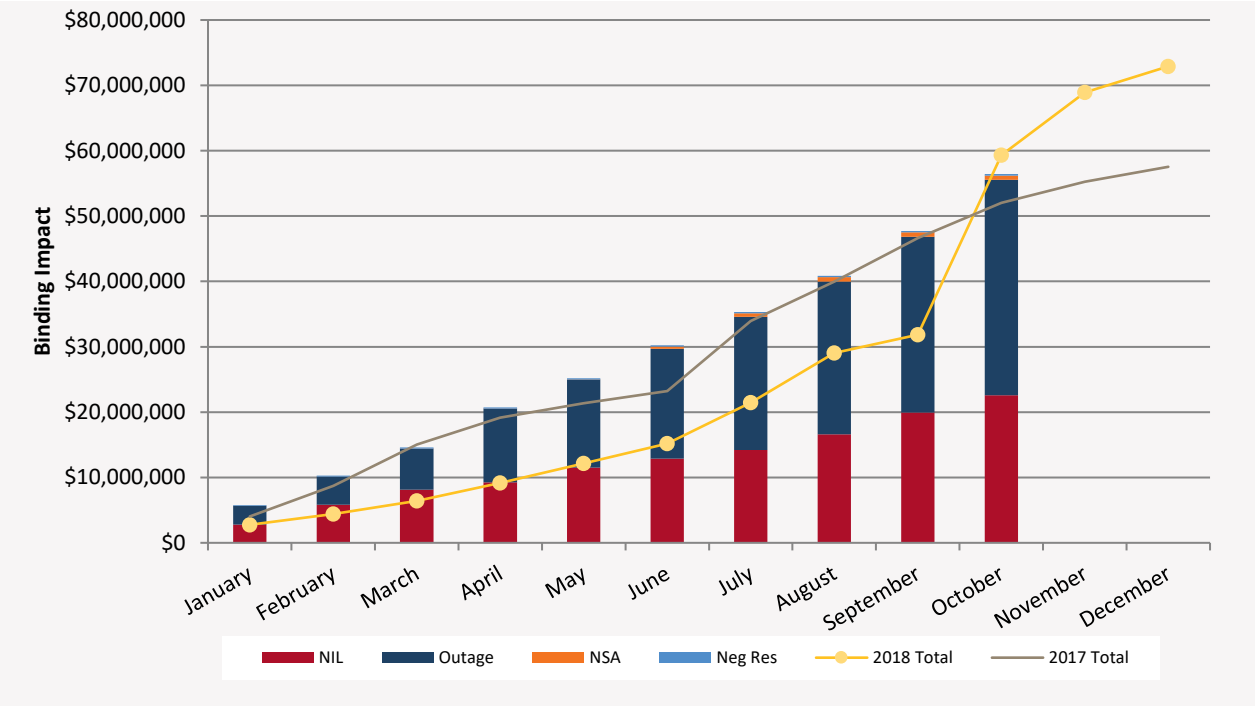
Figure 3 Binding by limit type



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_VS_LB_CAN_50	Limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement when SA is at risk of separation.	65	16,581% (103.35)	368% (28.87)
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.	36	4,596% (282.63)	329% (118.31)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
T>T_SH_TX	Out = Sheffield 220/110kV transformer, West Coast 110/220 kV parallel open, avoid O/L the Burnie to Sheffield 220kV line or Burnie No. 2 220/110 kV txfmr for loss of the remaining Sheffield 220/110kV transformer	3	2,697% (23.49)	1,171% (19.07)
N^N-LS_SVC	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; TG formulation only	17	1,623% (99.33)	211% (41.91)
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.	37	1,318% (267.04)	137.64% (108.59)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	439	311% (339.23)	11.14% (31.78)
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	14	262% (110.75)	106.03% (49.53)
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]	14	166% (118.78)	70.29% (64.23)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	142	118.17% (351.91)	33.78% (116.85)
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.	4	98.33% (99.95)	98.33% (99.95)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V_VS_LB_CAN_50: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_HWSM_V1: Investigated and no improvement can be made to the constraint equation at this stage.

N^N-LS_SVC: Investigated and constraint equation was updated on 27/08 to improve PD performance.

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.

V^SML_BUDP_3: 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.

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 October 2019.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Barkers Inlet Ps	15 October 2019	SA1	New Generator
Lake Bonney Battery (Load Mode) MW	8 October 2019	SA1	New Generator
Commissioning of Grafton East Substation	25 October2019	NSW	Grafton East Substation has been energised at 132kV. The existing Coffs Harbour – Koolkhan 96H 132kV line has now been cut to from two lines connecting to Grafton East Substation. The new transmission line names are Coffs Harbour – Grafton East 96H 132 kV line and Koolkhan – Grafton East 9W0 132 kV line.
Commissioning of Haunted Gully Terminal Station	30 October 2019	VIC	Haunted Gully Terminal Station has been energised at 500kV. The existing Moorabool-Tarrone No 1 500kV transmission line has now been cut to form two lines connecting to Haunted Gully Terminal Station. The new transmission line names are Moorabool – Haunted Gully No 1 500 kV line and Haunted Gully – Moorabool No 1 500kV line

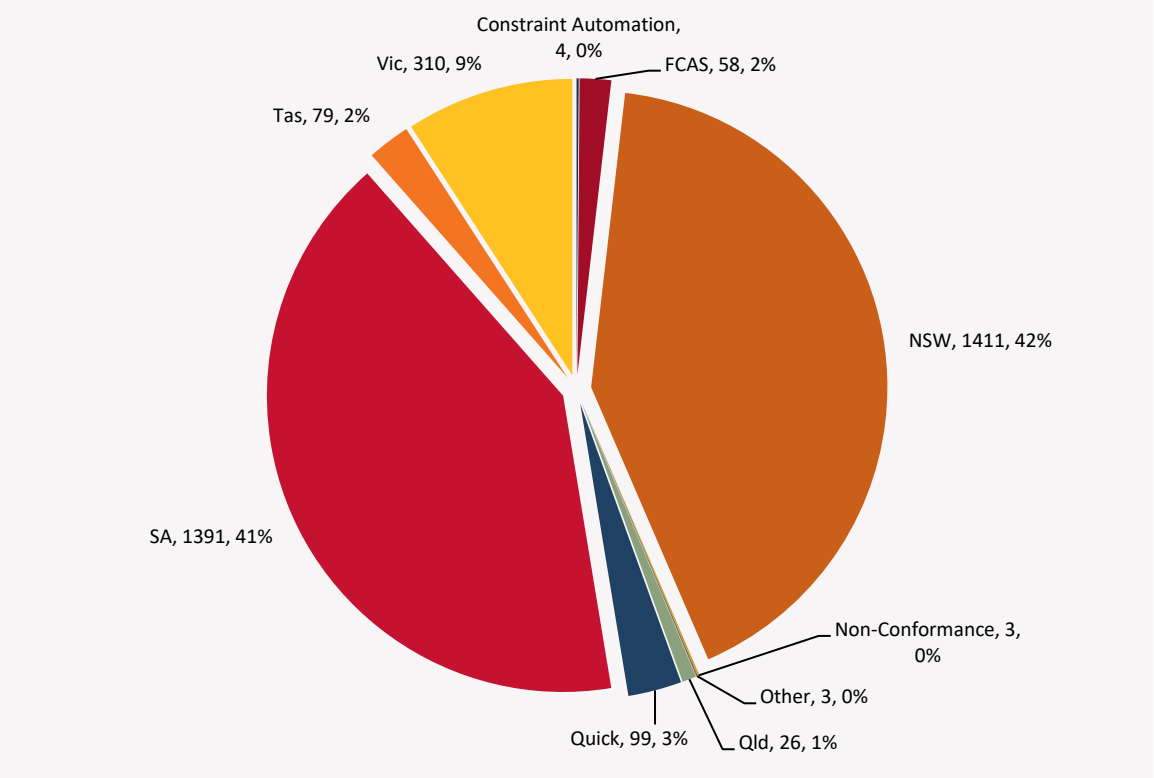
3.1 Constraint Equation Changes

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