AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

June 2021

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 June 2021. 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
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.	1043 (86.91)	15/06/2021
T_MRWF_FOS	Limit Musselroe wind farm due to upper limit on Tasmanian generator events. Limit is 153 MW (effective 144 MW at the connection point at Derby)	1003 (83.58)	1/01/2020
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	890 (74.16)	21/08/2013
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	859 (71.58)	21/01/2021
N^^V_CNCW_1	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W), avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	731 (60.91)	31/03/2021
S>NIL_MHNW1_MHNW2	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	555 (46.25)	22/04/2021
SVML^NIL_MH-CAP_ON	Out=NIL, SA to Vic on ML upper transfer limit to manage voltage collapse at Monash (Note: applies when capacitor banks at Monash are available and I/S for switching.)	507 (42.25)	13/01/2021
Q>NIL_BI_FB	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines	486 (40.5)	24/08/2020
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	467	11/02/2021

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
		(38.91)	
N_BROKENH1_ZERO	Broken Hill Solar Farm upper limit of 0 MW and all inverters disconnected.	392 (32.66)	10/08/2020

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
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	2,369,135	23/09/2020
F_Q++LDMU_R6	Out = Liddell to Muswellbrook (83) line, Qld Raise 6 sec Requirement	1,432,814	10/09/2019
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.	1,061,012	15/06/2021
Q>NIL_BI_FB	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines	662,402	24/08/2020
F_Q++LDMU_R60	Out = Liddell to Muswellbrook (83) line, Qld Raise 60 sec Requirement	493,165	10/09/2019
N_BROKENH1_ZERO	Broken Hill Solar Farm upper limit of 0 MW and all inverters disconnected.	479,238	10/08/2020
N_SUNRSF1_ZERO	Sunraysia 1 solar farm upper limit of 0 MW and all inverters disconnected.	470,389	10/08/2020
F_Q++LDTW_R6	Out = Liddell to Tamworth (84) line, Qld Raise 6 sec Requirement	443,542	11/09/2019
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	419,888	11/02/2021
F_Q++LDTW_R60	Out = Liddell to Tamworth (84) line, Qld Raise 60 sec Requirement	395,978	11/09/2019

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)

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.

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
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	187 (15.58)	23/09/2020
V::S_SETB_MAXG_2	Out= one South East to Tailem Bend 275kV line; Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available). (NOTE: with both Black Range series capacitors O/S).	19 (1.58)	15/06/2021
Q_STR_7C9C_MEWF	Mt Emerald WF to 100% of Max capacity if Stan>=3+CalB+C>=2+Glad>=3+ (Stan+Cal+Glad) >=9+Kar>2,NQLD>450&470(AVG),Ross_FN>250&270(AVG).80% if Stan>=3+Glad>=2+ (Stan+Cal+Glad) >=7+Kar>2 or if Stan>=3+Glad>=2+(Stan+Cal+Glad)>=6+Kar>2 .Zero otherwise	11 (0.91)	2/06/2021
N_BROKENH1_0INV	Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	8 (0.66)	22/12/2020
NSA_V_BDL02_40	Bairnsdale Unit 2 >= 40 MW for Network Support Agreement	7 (0.58)	21/08/2013
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	7 (0.58)	4/05/2018
S::V_TBSE_TBSE_2	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps O/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	5 (0.41)	5/08/2019
T_GO_300	Discretionary 300 MW upper limit on total Gordon generation	3 (0.25)	5/06/2015
S:V_PA_SVC_420	Out= one Para SVC, Oscillatory stability limit for SA to VIC on Heywood upper transfer limit of 420 MW	2 (0.16)	7/08/2018
SV_420_DYN	SA to Victoria on Heywood upper transfer limit of 420 MW. Limit is dynamically reduced when actual flow exceeds limit by at least 10 MW. Limit is reduced by amount of exceedance, capped at 25 MW	2 (0.16)	1/12/2020

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
NRM_QLD1_NSW1	Constraint equation violated for 187 non-consecutive DIs on 03/06/2021, 04/06/2021, 05/06/2021, 15/06/2021, 21/06/2021 and 25/06/2021 with max violation of 186.34 MW occurring on 03/06/2021 at 1725 hrs. Constraint equation violation occurred due to competing requirements with the export limit which was set by F_Q++LDMU_R6, F_Q++LDMU_R60, F_Q++LDMU_R5, NQTE_ROC, F_Q++ARTW_R6 and N>N-NIL_LSDU.
V::S_SETB_MAXG_2	Constraint equation violated for 19 non-consecutive DIs on 02/06/2021 and 03/06/2021 with max violation of 37.68 MW occurring on 02/06/2021 at 1245 hrs. Constraint violated due to competing requirements with the import constraint limit which was set by S::V_TBSE_TBSE_2 and V::N_DDSM_V1.

Constraint Equation ID (System Normal Bold)	Description
Q_STR_7C9C_MEWF	Constraint equation violated for 11 non-consecutive DIs on 09/06/2021 and 21/06/2021 with violation degree of 0.001 MW. Constraint equation violation occurred due to Mt Emerald Wind Farm exceeding its turbine limit.
N_BROKENH1_0INV	Constraint equation violated for 8 non-consecutive DIs on 11/06/2021, 15/06/2021 and 16/06/2021 with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit.
NSA_V_BDL02_40	Constraint equation violated for 7 consecutive DIs on 10/06/2021 with max violation of 40 MW occurring at 0600 hrs, 0605 hrs, 0610 hrs, 0625 hrs and 0630 hrs. Constraint equation violation occurred due to Bairnsdale unit 2 being limited by its start-up profile.
F_T_AUFLS2_R6	Constraint equation violated for 7 non-consecutive DIs on 07/06/2021, 24/06/2021 and 28/06/2021 with max violation of 3.04 MW. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
S::V_TBSE_TBSE_2	Constraint equation violated for 5 DIs on 02/06/2021 with max violation of 27.01 MW occurring at 1205 hrs. Constraint equation violated due to competing requirements with the export constraint limit which was set by V_S_NIL_ROCOF and V::S_SETB_MAXG_2.
T_GO_300	Constraint equation violated for 3 DIs on 17/06/2021 at 1225 hrs, 1240 hrs and 1310 hrs with max violation of 3.73 MW at 1310 hrs. Constraint equation violated due to Gordon Hydro non-conforming.
S:V_PA_SVC_420	Constraint equation violated for 2 DIs on 17/06/2021 at 1220 hrs and 1225 hrs with max violation of 58.71 occurring at 1220 hrs. Constraint equation violated due to Vic-SA interconnector non-conforming.
SV_420_DYN	Constraint equation violated for 2 DIs on 17/06/2021 at 1220 hrs and 1225 hrs with max violation of 58.71 MW occurring at 1220 hrs. Constraint equation violated due to Vic-SA interconnector non-conforming.

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)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1348 (112.33)	283.56 (468.14)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	859 (71.58)	0.0 (0.0)
N^^V_CNCW_1	VIC1-NSW1 Import	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W), avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	728 (60.67)	-194.47 (-776.68)
N^^V_CNCW_1	V-S-MNSP1 Import	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W), avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	692 (57.67)	37.37 (-166.52)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	584 (48.67)	230.21 (446.01)
S>NIL_MHNW1_MHNW2	V-S-MNSP1 Export	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	513 (42.75)	149.79 (167.78)
SVML^NIL_MH-CAP_ON	V-S-MNSP1 Import	Out=NIL, SA to Vic on ML upper transfer limit to manage voltage collapse at Monash (Note: applies when capacitor banks at Monash are available and I/S for switching.)	505 (42.08)	-146.55 (-171.57)
F_MAIN++ML_L6_0400	T-V-MNSP1 Import	Out = Nil, Lower 6 sec requirement for a Mainland Load Event, ML = 400, Basslink able transfer FCAS	478 (39.83)	-358.1 (-446.0)
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	433 (36.08)	-175.9 (-446.0)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	431 (35.92)	1004.26 (1310.06)

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

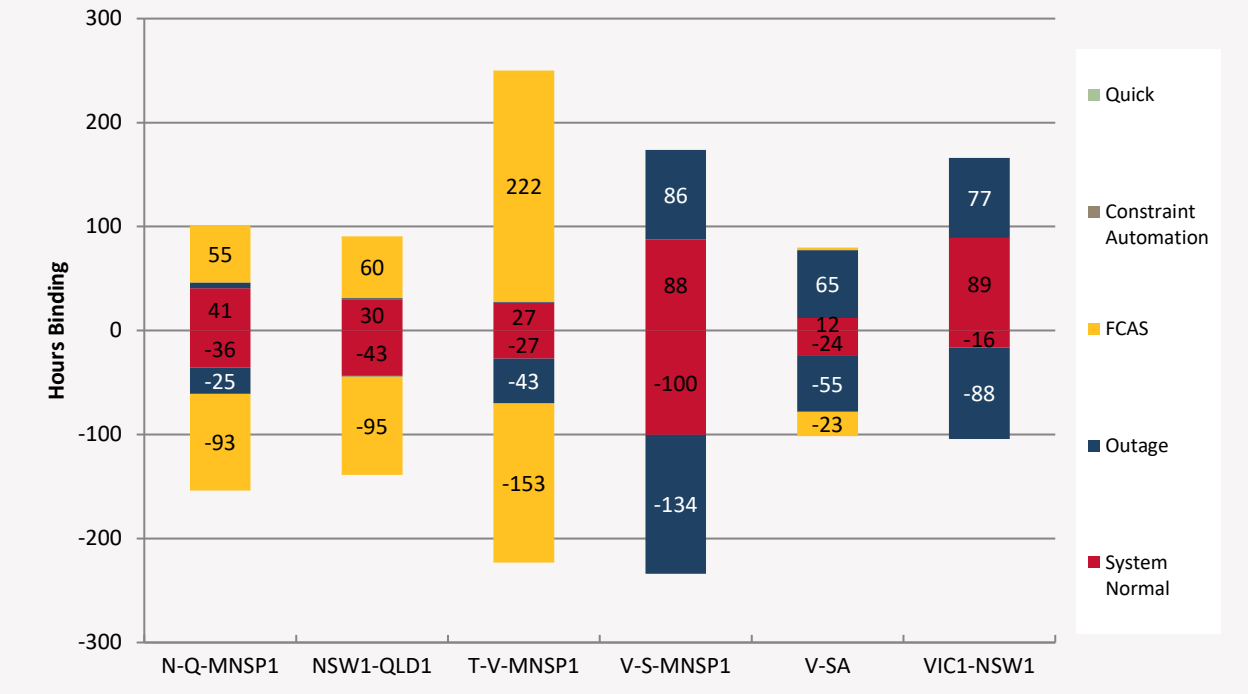
Non-real time constraint automation was not used.

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.

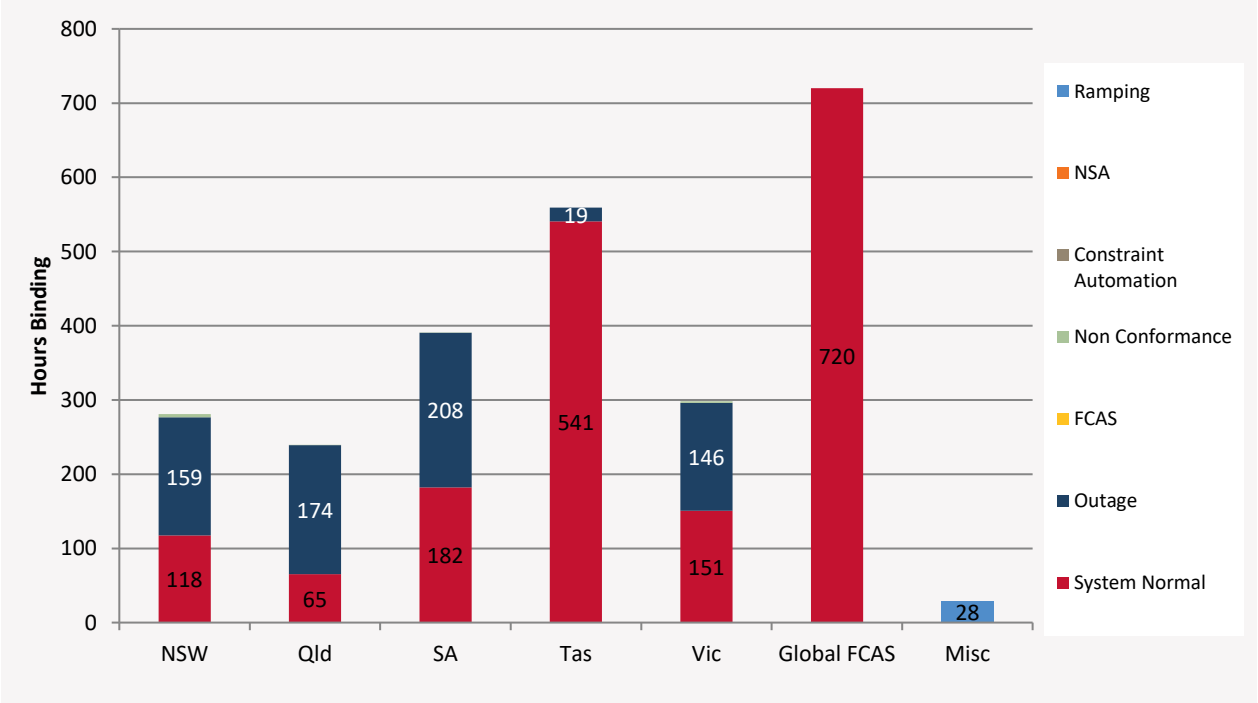
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

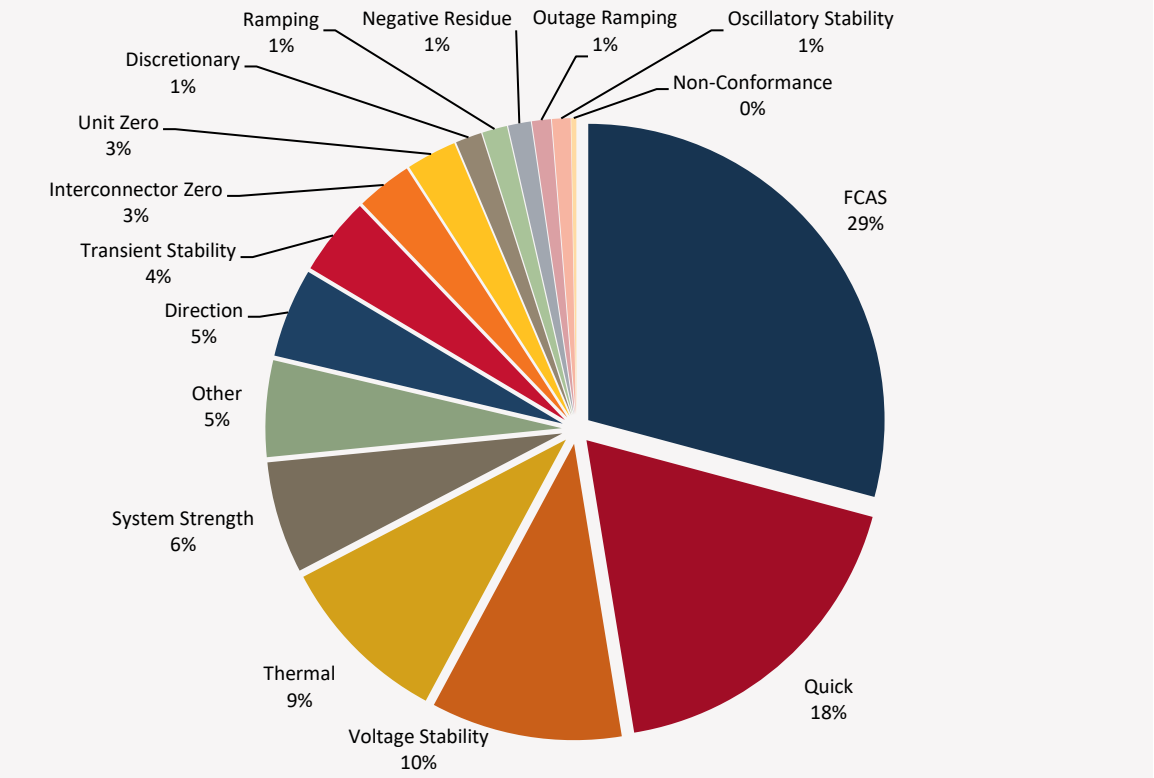
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for June 2021 that the different types of constraint equations bound.

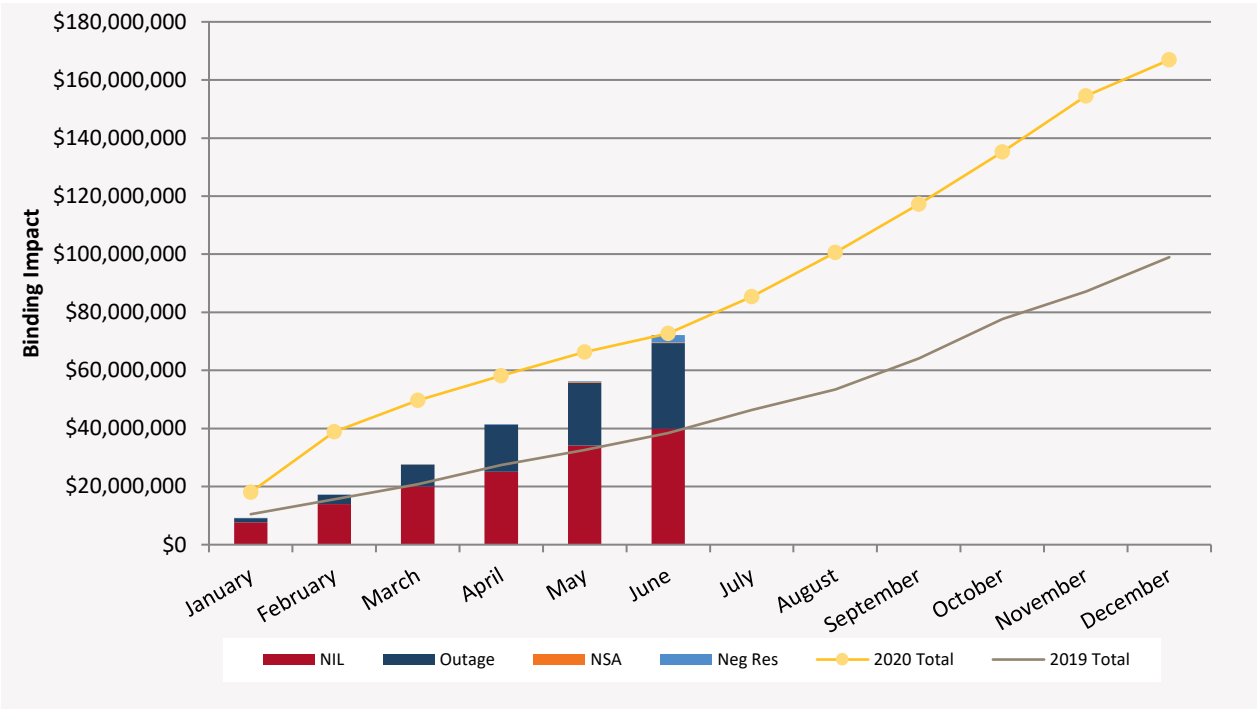
Figure 3 Binding by limit type



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::S_SETB_MAXG_2	Out= one South East to Tailem Bend 275kV line; Vic to SA Transient Stability limit for loss of the largest generation block in SA (South East Capacitor Available). (NOTE: with both Black Range series capacitors O/S).	23	1,030,592% (121.41)	45,559% (37.12)
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	44	4,365% (71.5)	360% (28.88)
V::N_SMF2_V1	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 220 kV.	51	4,052% (284.12)	328% (119.89)
S::V_TBSE_TBSE_2	Out = one Tailembend-South East 275kV line (Note: with both Black Range series caps O/S); SA to VIC Transient Stability limit for loss of other Tailembend-South East 275kV lines.	40	2,272% (46.73)	128.59% (12.07)
V>>V_DDSM_1	Out= Dederang to South Morang 330kV line, avoid O/L Ballarat to Bendigo 220kV line on trip of the remaining South Morang to Dederang 330kV line, Feedback	86	1,263% (222.26)	127.19% (101.15)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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	165	593% (110.92)	73.19% (28.01)
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	81	559% (222.1)	57.4% (68.55)
V::N_DDSM_V1	Out = Dederang to South Morang 330kV line, prevent transient instability for fault and trip of the parallel Dederang to South Morang 330kV line, VIC accelerates, Yallourn W G1 on 220 kV.	62	393% (209.02)	45.41% (60.88)
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]	61	215% (123.28)	59.16% (50.47)
T::T_NIL_1	Out = NIL, prevent transient instability for fault and trip of a Farrell to Sheffield line, Swamp if less than 3 synchronous West Coast units generating or Farrell 220kV bus coupler open or Hampshire 110kV line is closed.	265	153% (387.65)	28.19% (92.57)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::S_SETB_MAXG_2: Investigated and no improvement can be made to the constraint equation at this stage.

V^SML_BUDP_3: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_SMF2_V1: Investigated and no improvement can be made to the constraint equation at this stage.

S::V_TBSE_TBSE_2: Investigated and no improvement can be made to the constraint equation at this stage.

V>>V_DDSM_1: Investigated and no improvement can be made to the constraint equation at this stage.

S>SE6161_SETX2_SGBL: Investigated and no improvement can be made to the constraint equation at this stage.

N^^V_DDSM1: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_DDSM_V1: 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.

T::T_NIL_1: Investigated and no improvement can be made to the constraint equation at this stage.

3. Generator / Transmission Changes

One of the main drivers for changes to constraint equations is from power system change, whether this is the addition or removal of plant (either generation or transmission). The following table details changes that occurred in for June 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Wagga North Solar Farm	8 June 2021	Vic	New Generator
Kennedy Wind Farm	22 June 2021	QLD	New Generator
Kennedy Solar Farm	22 June 2021	QLD	New Generator
Gunnedah solar farm	29 June 2021	NSW	New Generator

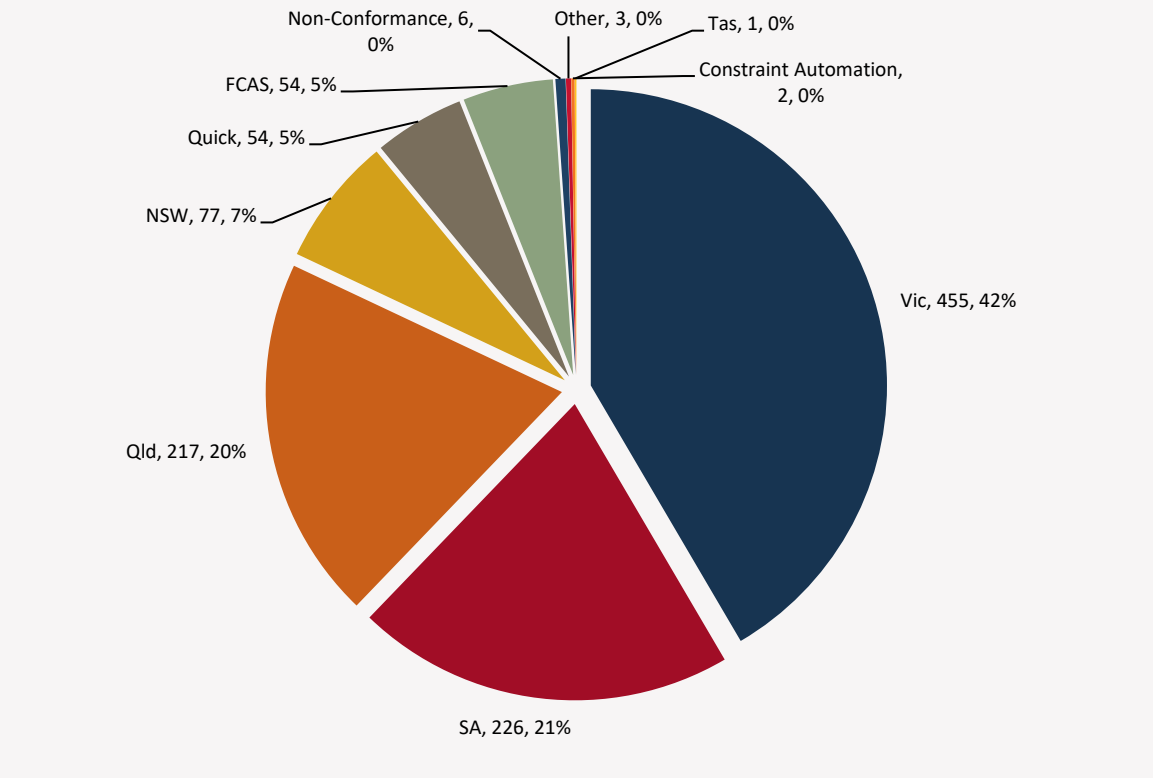
3.1 Constraint Equation Changes

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: https://www.aemo.com.au/energy-systems/market-it-systems/nem-guides/wholesale-it-systems-software

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