AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

May 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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Contents

Tables

Figures

1. Introduction

This report details constraint equation performance and transmission congestion related issues for May 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
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	2872 (239.33)	21/08/2013
S^SETX_GEN_CAP	Out= One South East 275/132kV transformer O/S, avoid local voltage collapse on trip of remaining South East transformer,	2648 (220.66)	28/05/2019
N^N_CHLS_1	Out= Coffs Harbour to Lismore (89), avoid voltage collapse on trip of Koolkhan to Lismore (967), swamp out when all 3 Directlink O/S	1572 (131.0)	22/06/2020
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.	1359 (113.25)	26/03/2020
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)	1151 (95.91)	1/01/2020
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.)	851 (70.91)	13/01/2021
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.	780 (65.0)	9/06/2021
N^^N_NIL_3	Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse for contingency trip of Bendigo-Kerang 220kV line in NW Victoria	671 (55.91)	31/03/2021

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V::N_DDSM_V2	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 500 kV.	664 (55.33)	11/06/2021
N^N-89_LSTX_SVC	Out= Coffs Harbour to Lismore (89) line and 330/132kV Lismore Txs O/S, and Lismore SVC in reactive power control mode, avoid Voltage collapse on Koolkhan to Lismore (967) trip; TG formulation only	631 (52.58)	22/06/2020

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
S^SETX_GEN_CAP	Out= One South East 275/132kV transformer O/S, avoid local voltage collapse on trip of remaining South East transformer,	1,875,675	28/05/2019
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.	760,394	9/06/2021
Q>NIL_EMCM_6056	Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder	633,554	16/04/2021
S_SECB_LG-1	Out= South East 132kV CB 6186 Or 6187, Oscillatory stability limit for the loss of Penola West-South East 132kV line,Ladbroke Grove 1 can generate up to 40MW on a single unit OR 20MW max per unit (40MW total output)	615,069	13/08/2019
Q>NIL_BI_FB	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines	454,796	24/08/2020
Q_NIL_STRGTH_KIDSF	Out = Nil, limit Kidston SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	419,611	10/06/2021
S_SECB_LG3	Out= South East 132kV CB 6186 Or 6187, Oscillatory stability limit for the loss of Penola West-South East 132kV line, max generation of Ladbrok Grove Gen 1 and 2 to a total of 40 MW	389,946	26/05/2017

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
Q_NIL_STRGTH_HAMSF	Out = Nil, limit Hamilton SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	381,833	10/06/2021
Q_NIL_STRGTH_RRSF	Out = Nil, limit Ross River SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	380,844	10/06/2021
Q_NIL_STRGTH_HAYSF	Out = Nil, limit Hayman SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	366,182	10/06/2021

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
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	11 (0.91)	6/05/2015
F_T+NIL_ML_L6	Out = Nil, Lower 6 sec requirement for a Tasmania Load Event, Basslink unable to transfer FCAS	9 (0.75)	3/03/2021
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, Waddamana to Cattle Hill or Pieman to Granville Harbour line, Basslink unable to transfer FCAS	8 (0.66)	23/12/2020
N_DARLSF_FLT_110	Limit Darlington Pt Solar Farm upper limit to 110 MW to manage post contingent voltage oscillation	6 (0.5)	14/01/2021
N_FINLYSF_FLT_55	Limit Finley solar farm upper limit to 55 MW to manage post contingent voltage oscillation	5 (0.41)	14/01/2021
Q_NIL_STRGTH_CLRSF	Out = Nil, limit Clare SF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone and Kareeya generators, Zero if it does not meet minimum generator online.	4 (0.33)	10/06/2021
N_WR_30_WT-INV	Limit White Rock wind/solar farm upper limit to 0 MW if number of wind turbine + inverter available exceed 30. Dispatch only. swamped out if Inverters are within the limit.	3 (0.25)	11/08/2020
N_FINLYSF_FLT_50	Limit Finley solar farm upper limit to 50 MW to manage post contingent voltage oscillation	2 (0.16)	14/10/2020
N_DARLSF_FLT_100	Limit Darlington Pt Solar Farm upper limit to 100 MW to manage post contingent voltage oscillation	2 (0.16)	14/10/2020
F_T++NIL_MG_R5	Out = Nil, Raise 5 min requirement for a Tasmania Generation Event, Basslink able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	2 (0.16)	12/04/2016

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
NSA_Q_BARCALDN	Constraint equation violated for 11 non-consecutive DIs on 12/05/2021 and 19/05/2021 with max violation of 19.14 MW occurring on 19/04/2021 at 0530 hrs. Constraint equation violation occurred due to Barcaldine GT non-conforming.
F_T+NIL_ML_L6	Constraint equation violated for 9 non-consecutive DIs on 9/05/2021, 10/05/2021, 13/05/2021, 16/05/2021 and 28/05/2021 with max violation of 35.76 MW occurring on 16/05/2021 at 35.76 MW. Constraint equation violated due to Tasmanian lower 6 second availability being less than the requirement.
F_T+NIL_WF_TG_R6	Constraint equation violated for 8 non-consecutive DIs on 09/05/2021, 11/05/2021, 20/05/2021 and 26/05/2021 with max violation of 13.27 MW occurring on 26/05/2021 at 1150 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
N_DARLSF_FLT_110	Constraint equation violated for 6 non-consecutive DIs on 14/05/2021 with a max violation of 14 MW occurring at 1255 hrs. Constraint equation violation occurred due to Darlington Pt Solar Farm non-conforming.
N_FINLYSF_FLT_55	Constraint equation violated for 5 DIs on 14/05/2021 with max violation of 30.19 MW occurring at 1430 hrs. Constraint equation violation occurred due to Finley solar Farm non-conforming.
Q_NIL_STRGTH_CLRSF	Constraint equation violated for 4 DIs on 25/05/2021 at 1420 hrs, 1425 hrs, 1430 hrs and 1435 hrs with violation degree 0.001 MW. Constraint equation violation occurred due to Clare Solar Farm exceeding its inverter limit.
N_WR_30_WT-INV	Constraint equation violated for 3 DIs on 17/05/2021 at 0735 hrs, 0745 hrs and 0755 hrs with violation degree of 0.001 MW. Constraint equation violated due to White Rock wind/solar farm exceeding its turbine/inverter limit.
N_FINLYSF_FLT_50	Constraint equation violated for 2 DIs on 25/05/2021 at 1345 hrs and 1405 hrs with max violation of 37.58 MW occurring at 1405 hrs. Constraint equation violation occurred due to Finley solar Farm non-conforming.
N_DARLSF_FLT_100	Constraint equation violated for 2 DIs on 25/05/2021 at 0905 hrs and 0910 hrs with a max violation of 6.3 MW occurring at 0910 hrs. Constraint equation violation occurred due to Darlington Pt Solar Farm non-conforming.
F_T++NIL_MG_R5	Constraint equation violated for 2 DIs on 05/05/2021 at 0720 hrs and 0725 hrs with violation degree 4.61 MW. Constraint equation violation occurred due to Tasmania raise 5-minute service availability being less than the requirement.

2.4 Top 10 binding interconnector limit setters

Binding constraint equations can set the interconnector limits for each of the interconnectors on the constraint equation left-hand side (LHS). Table 5 lists the top (by binding hours) interconnector limit setters for all the interconnectors in the NEM and for each direction on that interconnector.

Table 5 Top 10 binding interconnector limit setters

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
SVML_ZERO	V-S-MNSP1 Import	SA to Vic on ML upper transfer limit of 0 MW	2721 (226.75)	0.0 (0.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N^N_CHLS_1	N-Q-MNSP1 Export	Out= Coffs Harbour to Lismore (89), avoid voltage collapse on trip of Koolkhan to Lismore (967), swamp out when all 3 Directlink O/S	1536 (128.0)	-66.51 (37.61)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1199 (99.92)	209.42 (446.01)
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.)	851 (70.92)	-147.63 (-162.19)
F_Q++MUTW_L6	NSW1-QLD1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	843 (70.25)	-370.3 (-770.49)
F_Q++MUTW_L6	N-Q-MNSP1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	813 (67.75)	-55.8 (-179.26)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	719 (59.92)	214.05 (446.01)
V::N_DDSM_V2	V-SA Import	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 500 kV.	660 (55.0)	-54.79 (-419.47)
N^N-89_LSTX_SVC	N-Q-MNSP1 Export	Out= Coffs Harbour to Lismore (89) line and 330/132kV Lismore Txs O/S, and Lismore SVC in reactive power control mode, avoid Voltage collapse on Koolkhan to Lismore (967) trip; TG formulation only	631 (52.58)	-111.67 (-22.0)
V::N_DDSM_V2	VIC1-NSW1 Export	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 500 kV.	596 (49.67)	547.39 (1274.82)

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

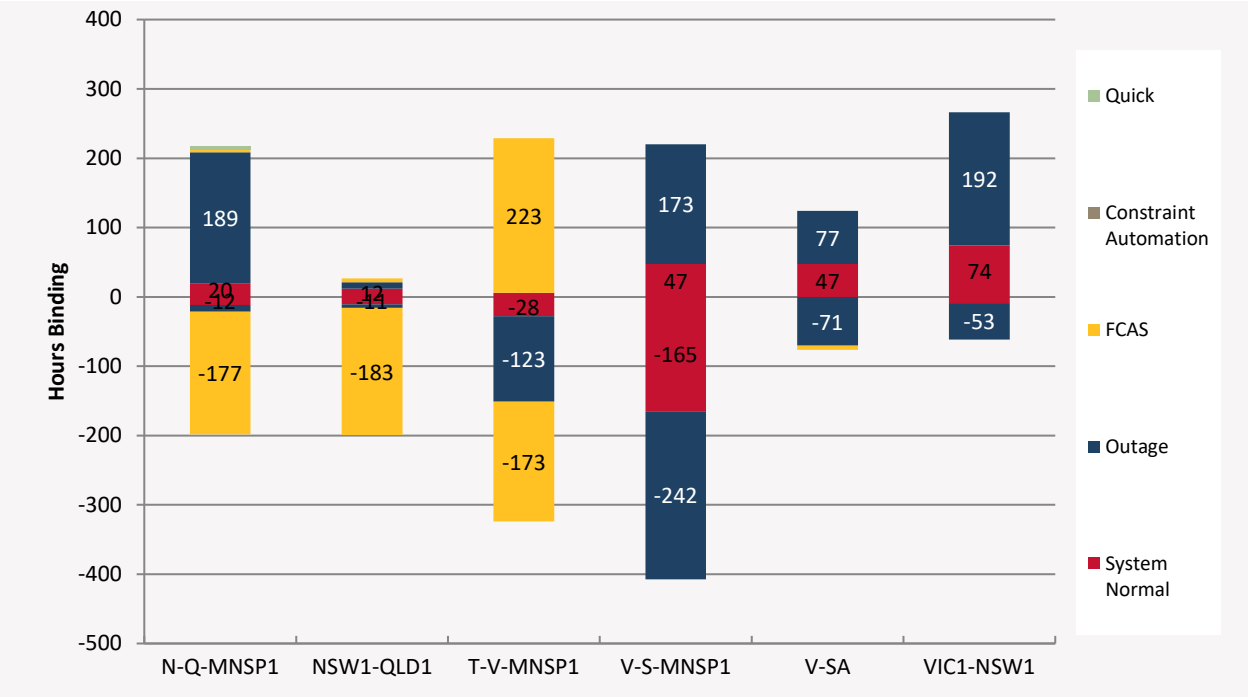
Non-real time constraint automation was not used.

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.

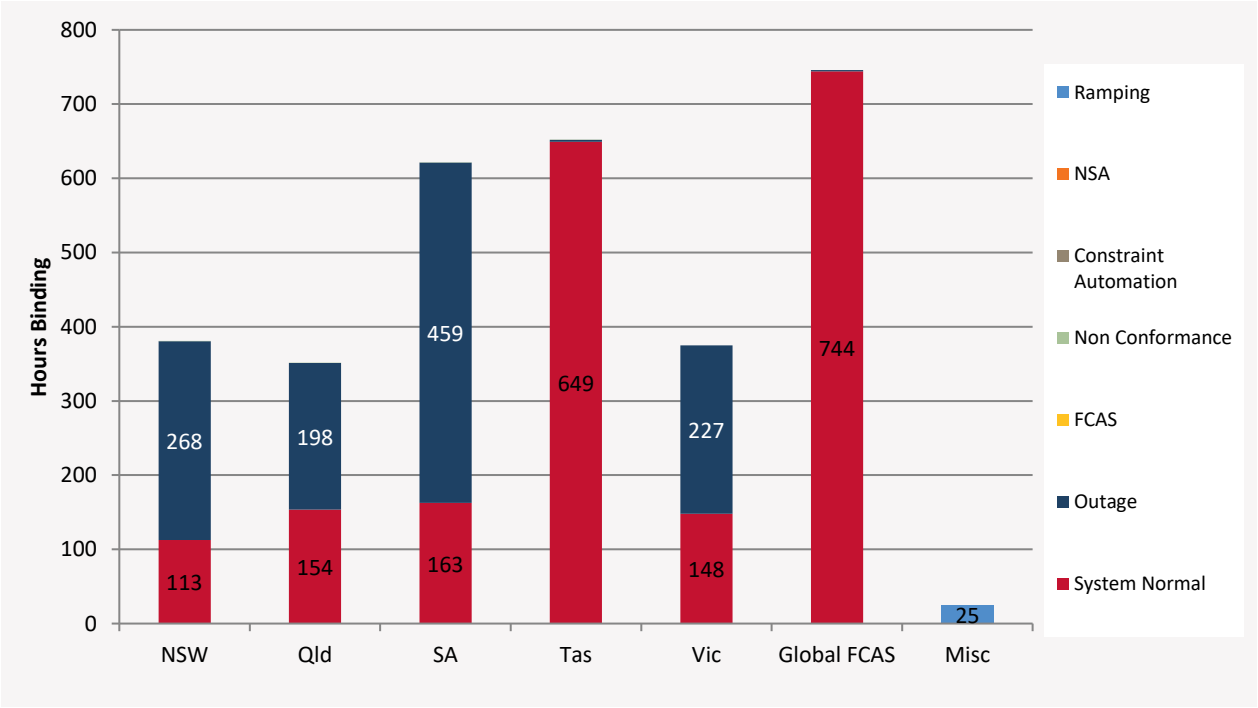
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

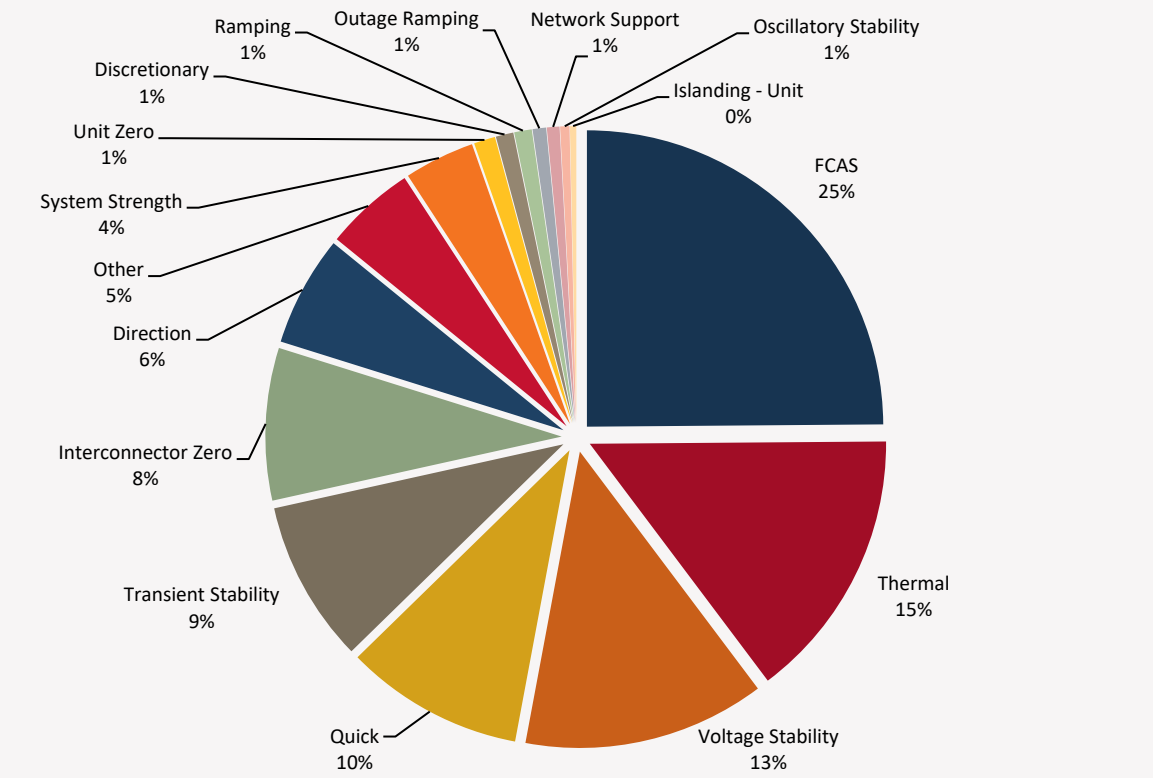
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

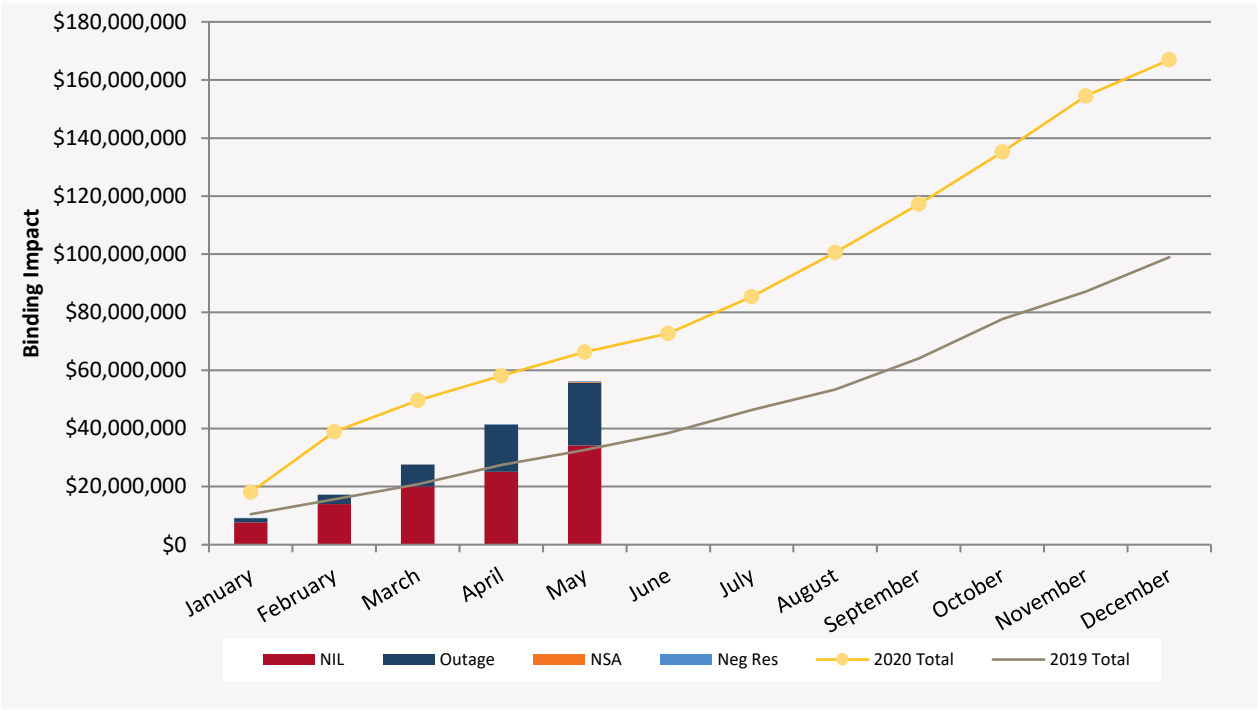
Figure 3 Binding by limit type



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>>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	137	36,032% (425.2)	517% (117.14)
V::N_SMF2_V2	Out = South Morang F2 500/330kV txfmr, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	179	15,183% (435.62)	328% (124.61)
V::N_SMF2_S2	Out = South Morang F2 500/330kV txfmr, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	67	4,730% (330.02)	245% (90.94)
N^N_CHLS_1	Out= Coffs Harbour to Lismore (89), avoid voltage collapse on trip of Koolkhan to Lismore (967), swamp out when all 3 Directlink O/S	273	1,968% (99.)	157% (32.6)
V_S_HEYWOOD_UFLS	Out= Nil, Limit Heywood flows when SA under frequency load shedding (UFLS) is insufficient (i.e. when UFLS blocks in SA <1000 MW) to manage for double-circuit loss of Heywood IC.Note: Constraint is swamped if UFLS blocks >= 1000 MW.	112	1,847% (9,486)	78.62% (642)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
S^SETX_GEN_CAP	Out= One South East 275/132kV transformer O/S, avoid local voltage collapse on trip of remaining South East transformer,	484	475% (113.13)	44.4% (22.15)
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.	499	461% (312.52)	24.64% (78.57)
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]	90	302% (150.09)	65.7% (48.94)
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.	9	163% (197.74)	79.32% (83.16)
N^N-89_LSTX_SVC	Out= Coffs Harbour to Lismore (89) line and 330/132kV Lismore Txs O/S, and Lismore SVC in reactive power control mode, avoid Voltage collapse on Koolkhan to Lismore (967) trip; TG formulation only	111	161% (77.45)	69.09% (44.25)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

V::N_SMF2_V2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_SMF2_S2: Investigated and no improvement can be made to the constraint equation at this stage.

N^N_CHLS_1: Investigated and no improvement can be made to the constraint equation at this stage.

V_S_HEYWOOD_UFLS: Investigated and no improvement can be made to the constraint equation at this stage. Changes to the status of the reactive devices between DS/PD contributes to the PD accuracy.

S^SETX_GEN_CAP: Constraint equation is currently under investigation.

T::T_NIL_1: 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.

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

N^N-89_LSTX_SVC: 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 May 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Junee Solar Farm	25 May 2021	NSW1	New Generator
Bango 999 Wind Farm	25 May 2021	NSW1	New Generator

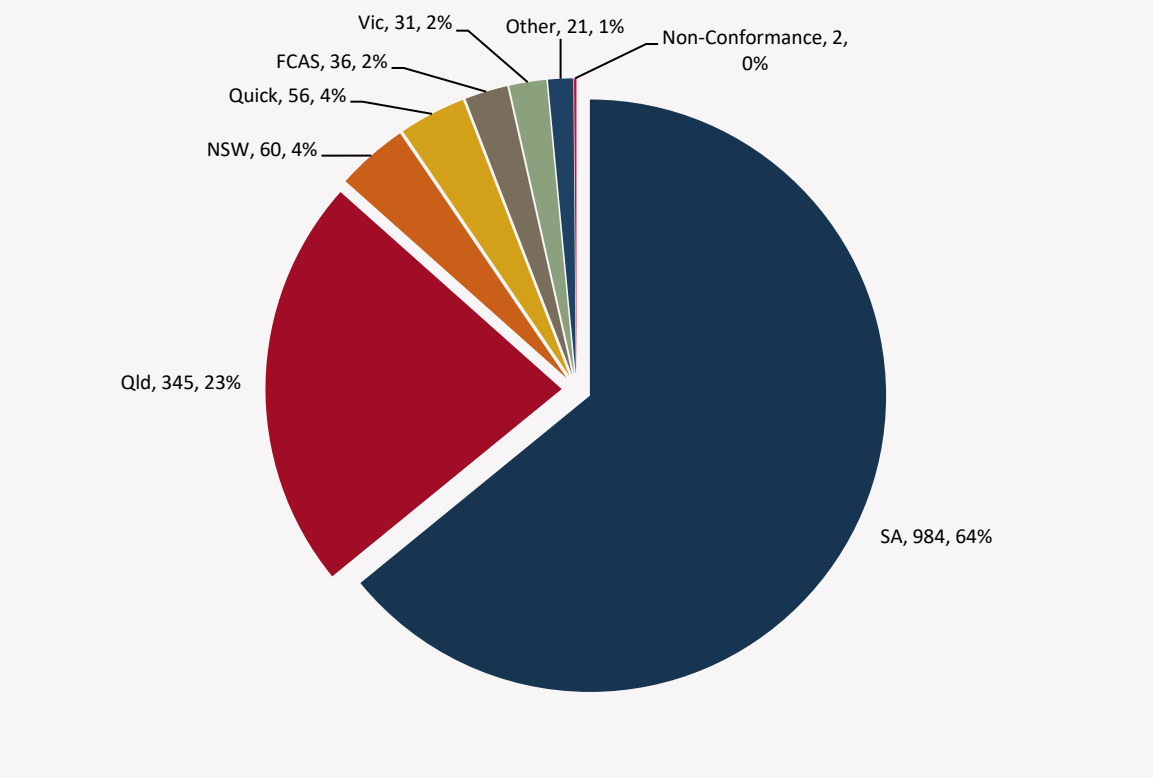
3.1 Constraint Equation Changes

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