AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

May 2020

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.

DISCLAIMER

This document or the information in it may be subsequently updated or amended. This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the National Electricity Law, the National Electricity Rules, or any other applicable laws, procedures or policies. AEMO has made every effort to ensure the quality of the information in this document but cannot guarantee its accuracy or completeness.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this document:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this document; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this document, or any omissions from it, or for any use or reliance on the information in it.

Contents

1.	**Introduction**	**5**
2.	**Constraint Equation Performance**	**5**
2.1	Top 10 binding constraint equations	5
2.2	Top 10 binding impact constraint equations	6
2.3	Top 10 violating constraint equations	7
2.4	Top 10 binding interconnector limit setters	8
2.5	Constraint Automation Usage	9
2.6	Binding Dispatch Hours	10
2.7	Binding Constraint Equations by Limit Type	11
2.8	Binding Impact Comparison	12
2.9	Pre-dispatch RHS Accuracy	12
3.	**Generator / Transmission Changes**	**14**
3.1	Constraint Equation Changes	14

Tables

Table 1	Top 10 binding network constraint equations	5
Table 2	Top 10 binding impact network constraint equations	6
Table 3	Top 10 violating constraint equations	7
Table 4	Reasons for constraint equation violations	8
Table 5	Top 10 binding interconnector limit setters	8
Table 6	Top 10 largest Dispatch / Pre-dispatch differences	12
Table 7	Generator and transmission changes	14

Figures

Figure 1	Interconnector binding dispatch hours	10
Figure 2	Regional binding dispatch hours	11
Figure 3	Binding by limit type	11
Figure 4	Binding Impact comparison	12

Figure 5 Constraint equation changes 15
Figure 6 Constraint equation changes per month compared to previous two years 15

1. Introduction

This report details constraint equation performance and transmission congestion related issues for May 2020. 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^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	1824 (152.0)	8/05/2020
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.	1753 (146.08)	20/05/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	1601 (133.41)	29/05/2020
Q_NIL_STRGTH_MEWF	Out = Nil, limit Mt Emerald WF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to TOA 393.	1358 (113.16)	27/04/2020
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	1333 (111.08)	20/04/2020
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	1287 (107.25)	25/11/2013
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.	885 (73.75)	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)	762 (63.5)	1/01/2020

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	654 (54.5)	15/05/2019
V_BANSF_BBD_60	Out = Nil, Limit Bannerton SF upper limit to 60 MW if Boundary Bend (BBD) loading is less than 10 MW, DS only. Swamp out if BBD loading is 10 MW or above.	593 (49.41)	16/08/2019

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 (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.	1,706,655	20/05/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	1,597,873	29/05/2020
Q_NIL_STRGTH_MEWF	Out = Nil, limit Mt Emerald WF output depends on the number units online in Stanwell, Callide B, Callide C, Gladstone, Townsville GT, Kareeya and Barron Gorge generators, Zero if it does not meet minimum generator online. Refer to TOA 393.	1,393,714	27/04/2020
V_BANSF_BBD_60	Out = Nil, Limit Bannerton SF upper limit to 60 MW if Boundary Bend (BBD) loading is less than 10 MW, DS only. Swamp out if BBD loading is 10 MW or above.	552,454	16/08/2019
S^SETX_GEN_CAP	Out= One South East 275/132kV transformer O/S, avoid local voltage collapse on trip of remaining South East transformer,	268,604	28/05/2019
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)	228,016	1/01/2020
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	141,483	4/05/2018

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_SECB_LG-2	Out= South East 132kV CB 6186 Or 6187, Oscillatory stability limit for the loss of Penola West-South East 132kV line,Ladbroke Grove 2 can generate up to 40MW on a single unit OR 20MW max per unit (40MW total output)	133,880	13/08/2019
T_T_FASH_10_N-2	Out = NIL, loss of both Farrell to Sheffield lines declared credible, Farrell 220 kV bus split, West Coast 220/110 kV parallel open, constrain John Butters and Bastyan to 0 MW as per TAS Networks advice	123,667	25/11/2019
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	111,267	2/12/2016

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
F_T+NIL_MG_RECL_R6	Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS	8 (0.66)	2/12/2016
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	6 (0.5)	4/05/2018
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	6 (0.5)	8/05/2020
NC_V_CHYTWF1	Non Conformance Constraint for CHERRY TREE WF	5 (0.41)	28/04/2020
N_FINLEYSF_49_INV	Limit Finley Solar Farm upper limit to 0 MW if number of inverter available exceed 49. Dispatch only. swamped out if Inverters are within the limit.	4 (0.33)	26/09/2019
F_T+LREG_0050	Tasmania Lower Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	4 (0.33)	29/01/2015
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	4 (0.33)	29/01/2015
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	4 (0.33)	30/04/2018
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	3 (0.25)	21/12/2018
S^SETX_GEN_CAP	Out= One South East 275/132kV transformer O/S, avoid local voltage collapse on trip of remaining South East transformer,	3 (0.25)	28/05/2019

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_T+NIL_MG_RECL_R6	Constraint equation violated for 8 non-consecutive DIs with max violation of 16.97 MW occurring on 09/05/2020 at 0230 hrs. Constraint equation violation occurred due to Tasmania's raise 6-second service availability was less than the requirement.
F_T_AUFLS2_R6	Consecutive equation violation occurred for 6 non-consecutive DIs with max violation of 64.7 MW occurring on 20/05/2020 at 0435 hrs. Constraint equation violated for the same reason as F_T+NIL_MG_RECL_R6.
N^N-LS_SVC	Constraint equation violated for 6 non-consecutive DIs with max violation of 28 MW occurring on 22/05/2020 at 0705 hrs. Constraint equation violated occurred due to competing requirements with import constraint N_X_MBTE_3B on 22/05/2020 at 0705 hrs and N_X_MBT2_B for the other 5 DIs.
NC_V_CHYTWF1	Constraint equation violated for 5 DIs with degrees violation of 0.6 MW on 28/05/2020 from 0905 hrs to 0925 hrs. Constraint equation violated due to Cherry Tree wind farm non-conforming.
N_FINLEYSF_49_INV	Constraint equation violated for 4 DIs with max violation of 50.94 MW occurring on 16/05/2020 at 0935 hrs. Constraint equation violation occurred due to Finley solar farm non-conforming
F_T+LREG_0050	Constraint equation violation occurred for 4 DIs with max violation of 50 MW occurring on 07/05/2020 at 1515 hrs. Constraint equation violated due to Tasmania's lower regulation service availability being less than the requirement.
F_T+RREG_0050	Constraint equation violation occurred for 4 DIs with max violation of 50 MW occurring on 07/05/2020 at 1515 hrs. Constraint equation violated due to Tasmania's raise regulation service availability being less than the requirement.
F_T_NIL_MINP_R6	Constraint equation violated for 4 DIs with max violation of 8.85 MW occurring on 26/05/2020 at 0720 hrs. Constraint equation violation occurred due to the same reason as F_T+NIL_MG_RECL_R6.
NSA_V_NPSD_100	Constraint equation violated for 3 DIs on 31/05/2020 at 0305 hrs to 0315 hrs with max violation of 43 MW occurring at 0305 hrs. Constraint equation violated due to Newport PS being limited by its start-up profile
S^SETX_GEN_CAP	Constraint equation violated for 2 DIs on 19/05/2020 at 1930 hrs and 1935 hrs, as well as 21/05/2020 at 0115hrs. Max violation of 20.99 MW occurred on 19/05/2020 at 1930 hrs. Constraint equation violation due to Lake Bonney 2 and 3 wind farms 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	1927 (160.58)	325.86 (446.01)
N^N-LS_SVC	N-Q-MNSP1 Export	Out= Lismore SVC O/S or in reactive power control mode, avoid Voltage collapse on Armidale to Coffs Harbour (87) trip; TG formulation only	1773 (147.75)	-58.07 (45.62)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	1285 (107.08)	-71.63 (-110.0)
F_MAIN++APD_TL_L60	T-V-MNSP1 Import	Out = Nil, Lower 60 sec Service Requirement for a Mainland Network Event-loss of APD potlines due to undervoltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS	962 (80.17)	120.3 (-437.76)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	699 (58.25)	353.14 (446.01)
F_Q++ARTW_L6	NSW1-QLD1 Import	Out = Armidale to Tamworth (85 or 86) line, Qld Lower 6 sec Requirement	647 (53.92)	-158.87 (-430.52)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	646 (53.83)	-73.25 (220.0)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	646 (53.83)	950.65 (1304.61)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	640 (53.33)	250.67 (446.01)
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	528 (44.0)	96.57 (-445.99)

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 6 – Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_BRIS_4DE45CFF	30/05/2020 14:50 to 30/05/2020 15:20	The automated constraint equation was created to manage the overloading of Ballarat to Waubra 220 kV line on the trip of the Bendigo to Kerang 220 kV line, under the existing system normal condition. The existing constraint equation, V>>V_NIL_9 was not adequate to manage the issue.
CA_BRIS_4DE47816	30/05/2020 15:25 to 31/05/2020 02:00	The constraint automation was an improved version of CA_BRIS_4DE45CF.

2.5.1 Further Investigation

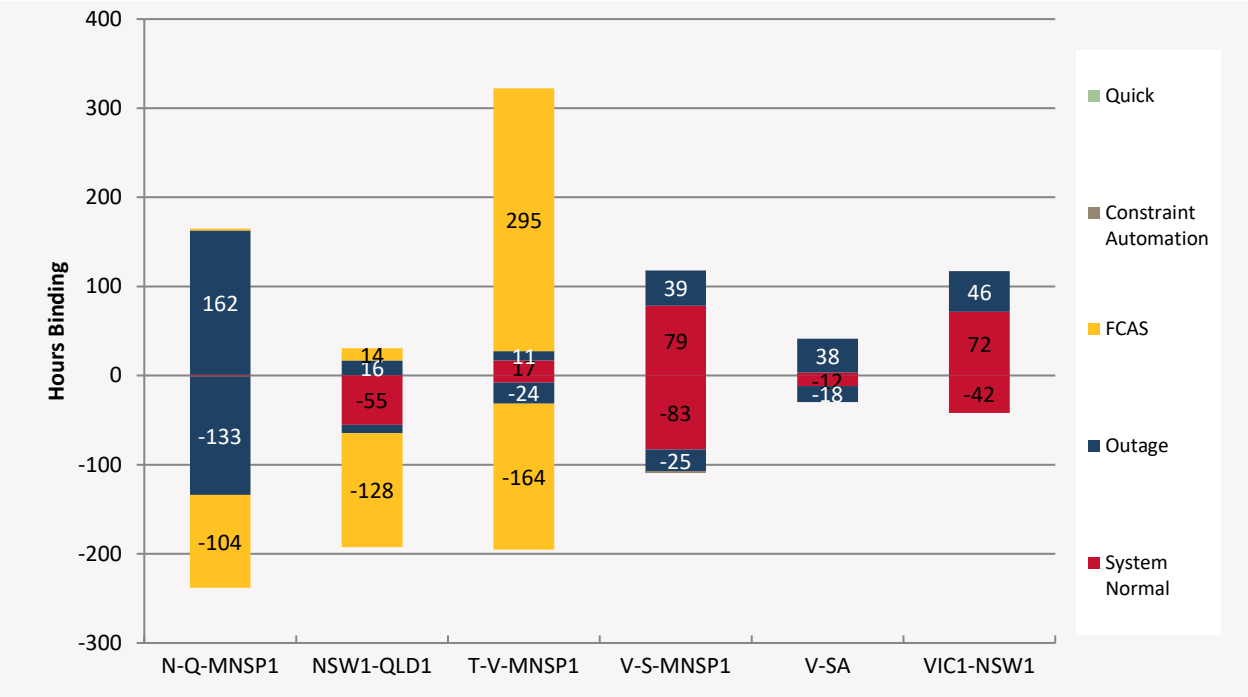
CA_BRIS_4DE45CFF and CA_BRIS_4DE47816: The existing system normal constraint equation (V>>V_NIL_9) has since been updated to manage the overloading of Ballarat to Waubra 220 kV line on the trip of Bendigo to Kerang 220 kV line

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.

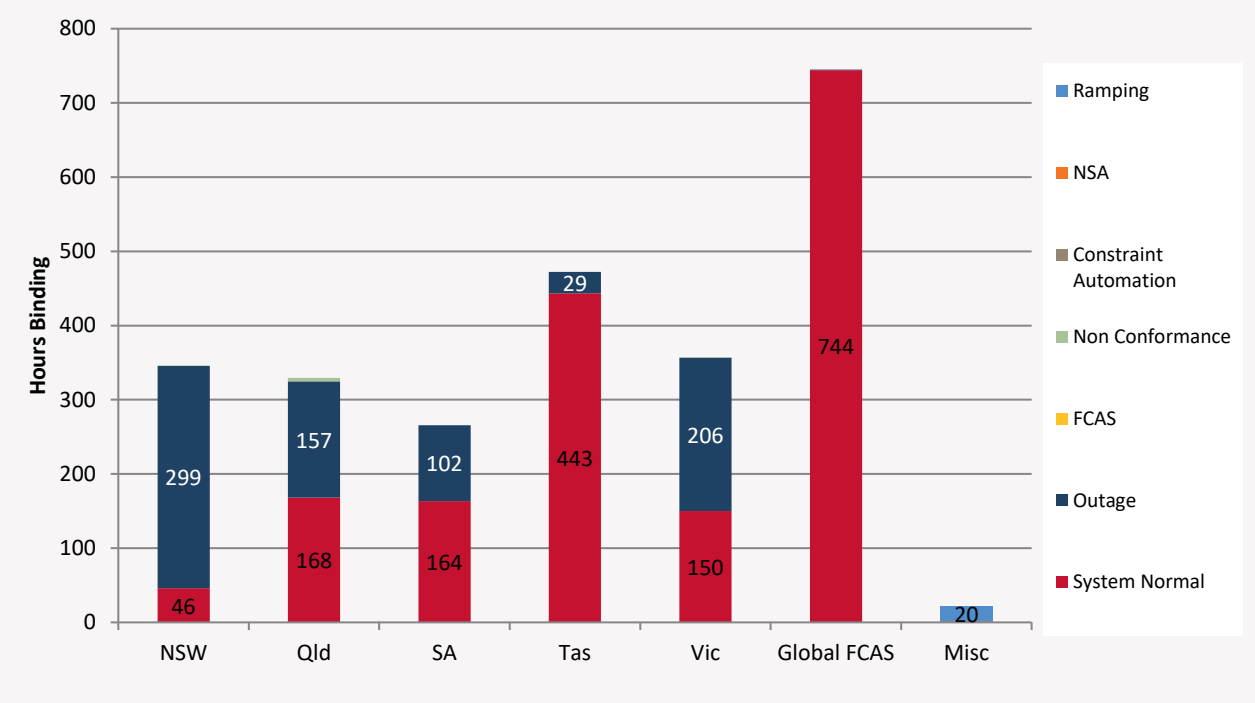
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

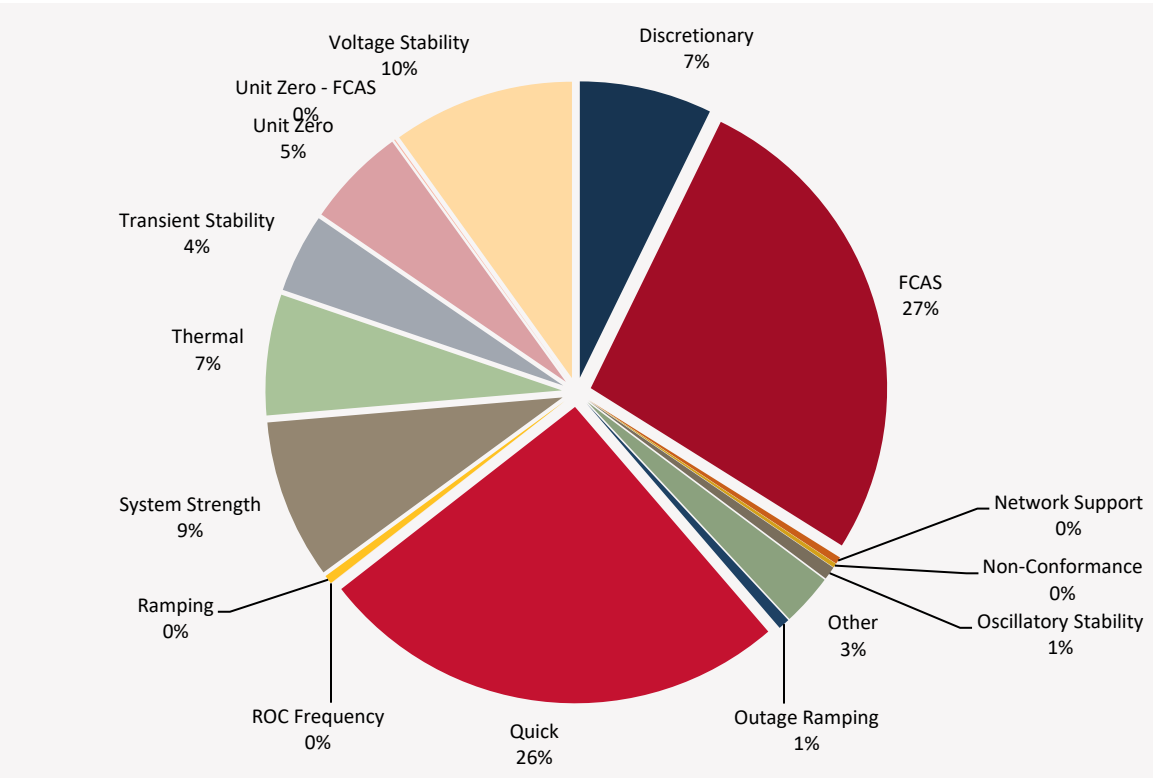
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for May 2020 that the different types of constraint equations bound.

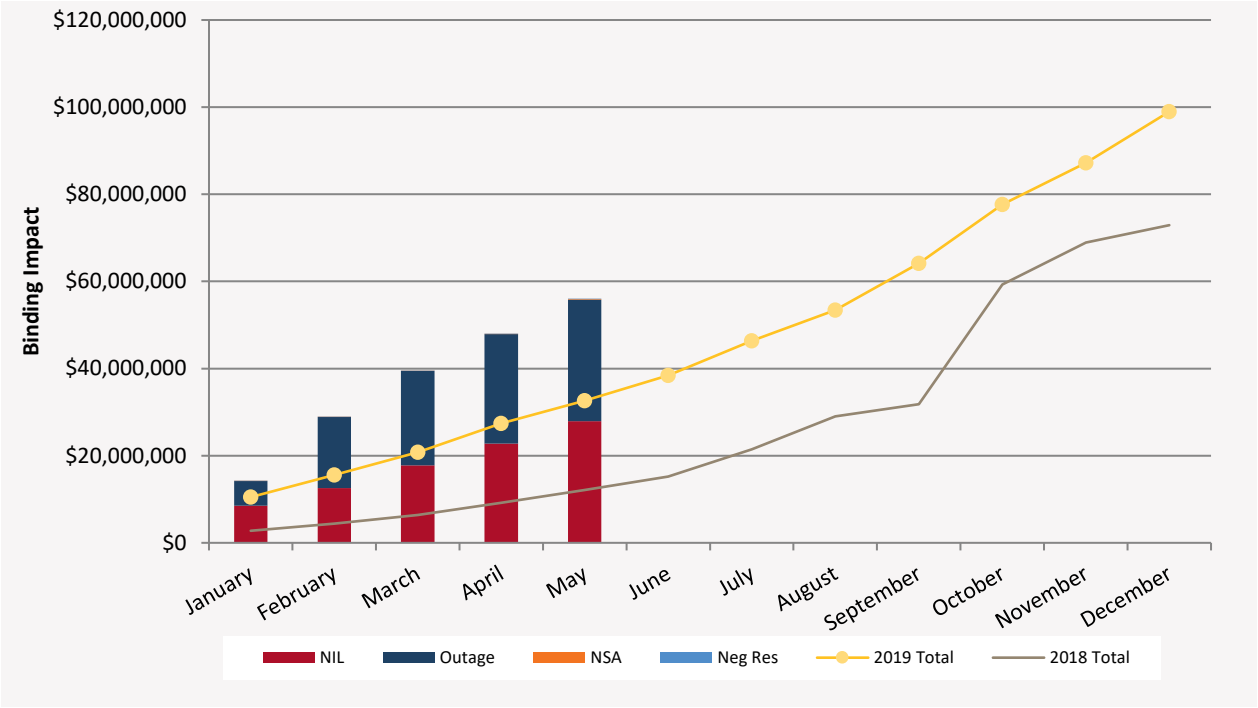
Figure 3 Binding by limit type



2.8 Binding Impact Comparison

The following graph compares the cumulative binding impact (calculated by summating the marginal values from the MCC re-run – the same as in section 2.2) for each month for the current year (indicated by type as a stacked bar chart) against the cumulative values from the previous two years (the line graphs). The current year is further categorised into system normal (NIL), outage, network support agreement (NSA) and negative residue constraint equation types.

Figure 4 Binding Impact comparison



2.9 Pre-dispatch RHS Accuracy

Pre-dispatch RHS accuracy is measured by the comparing the dispatch RHS value and the pre-dispatch RHS value forecast four hours in the future. The following table shows the pre-dispatch accuracy of the top ten largest differences for binding (in dispatch or pre-dispatch) constraint equations. This excludes FCAS constraint equations, constraint equations that violated in Dispatch, differences larger than ±9500 (this is to exclude constraint equations with swamping logic) and constraint equations that only bound for one or two Dispatch intervals. AEMO investigates constraint equations that have a Dispatch/Pre-dispatch RHS difference greater than 5% and ten absolute difference which have either bound for greater than 25 dispatch intervals or have a greater than $1,000 binding impact. The investigations are detailed in 2.9.1.

Table 7 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V::N_SMSC_S2	Out = one South Morang series capacitor, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	6	231,242% (114.54)	40,252% (71.58)
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	406	10,350% (120.62)	295% (36.44)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	50	7,120% (242.46)	234% (90.99)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	10	406% (366.81)	93.06% (133.48)
V::N_HWSM_S1	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, SA accelerates	11	331% (297.13)	123.59% (96.87)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	7	330% (24.5)	151% (16.84)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	50	290% (24.5)	66.46% (10.05)
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	29	243% (102.)	76.76% (102.)
V::N_MLTX_V2	Out = Moorabool Transformer 500/200kV, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	15	227% (184.27)	49.76% (84.67)
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	32	205% (151.7)	69.46% (147.07)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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.

N_X_MBTE_3B: Investigated and the mismatch was due to issues with forecasting of the Terranora load. The forecasting of the Terranora load has been improved in November 2018.

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

V_MURRAWRWF_MAX: 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 2020.

Table 8 Generator and transmission changes

Project	Date	Region	Notes
Bulgana Wind Farm	12 May 2020	VIC	New Generator
Goonumbla Solar Farm	12 May 2020	NSW	New Generator
Gullen Range Wind Farm 2	19 May 2020	NSW	New Generator

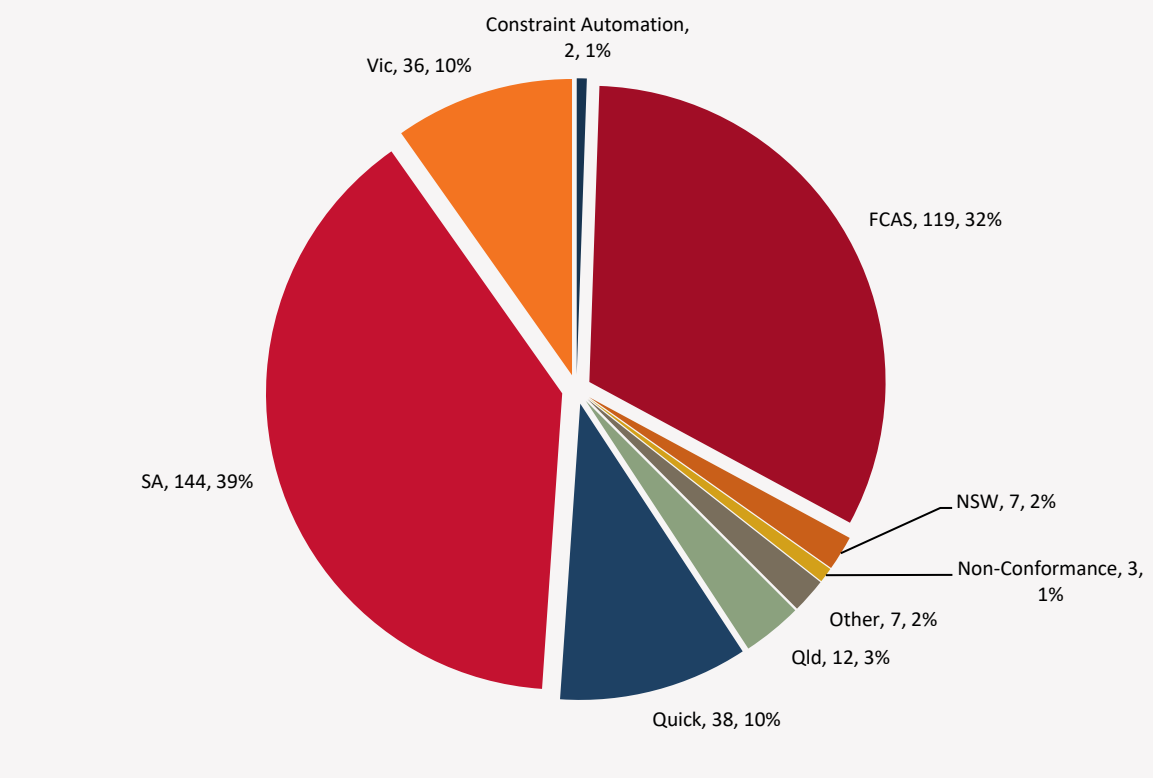
3.1 Constraint Equation Changes

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