AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

April 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.

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Contents

Tables

Figures

1. Introduction

This report details constraint equation performance and transmission congestion related issues for April 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
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)	2069 (172.41)	1/01/2020
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	2042 (170.16)	20/04/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	1916 (159.66)	31/03/2020
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.	1209 (100.75)	4/05/2020
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	964 (80.33)	15/05/2019
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	943 (78.58)	25/11/2013
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.	917 (76.41)	27/04/2020
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	849 (70.75)	2/10/2019

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	751 (62.58)	27/08/2018
N>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	638 (53.16)	22/01/2020

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
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	1,975,480	31/03/2020
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.	1,119,303	4/05/2020
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.	947,499	27/04/2020
N>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	651,644	22/01/2020
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)	606,679	1/01/2020
Q_NIL_STRGTH_HAUSF	Out = Nil, limit Haughton SF 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.	476,598	27/04/2020
Q_HAUGHTSF1_ZERO	Haughton Solar Farm upper limit of 0MW	320,381	14/11/2018
Q_MEWF1_ZERO	Mt Emerald Wind Farm upper limit of 0 MW	312,105	19/07/2018

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
N_BROKENH1_ZERO	Broken Hill Solar Farm upper limit of 0 MW	172,039	13/08/2015
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.	154,242	16/08/2019

2.3 Top 10 violating constraint equations

A constraint equation is violating when NEMDE is unable to dispatch the entities on the left-hand side (LHS) so the summated LHS value is less than or equal to, or greater than or equal to, the right-hand side (RHS) value (depending on the mathematical operator selected for the constraint equation). The following table includes the FCAS constraint equations. Reasons for the violations are covered in 2.3.1.

Table 3 Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	19 (1.58)	21/12/2018
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	12 (1.0)	23/05/2019
F_I+RREG_0220	NEM Raise Regulation Requirement greater than 200 MW	12 (1.0)	16/05/2019
F_I+LREG_0210	NEM Lower Regulation Requirement greater than 210 MW	12 (1.0)	16/05/2019
F_TASCAP_RREG_0220	Mainland Raise Regulation Requirement, Cap Tas contribution to 50 MW	12 (1.0)	16/05/2019
F_TASCAP_LREG_0210	Mainland Lower Regulation Requirement, Cap Tas contribution to 50 MW	12 (1.0)	16/05/2019
F_MAIN++RREG_0220	Mainland Raise Regulation Requirement greater than 200 MW, Basslink able transfer FCAS	12 (1.0)	16/05/2019
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	10 (0.83)	27/08/2018
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	5 (0.41)	20/04/2020
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	3 (0.25)	4/05/2018

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
NSA_V_NPSD_100	Constraint equation violation occurred for 19 DIs, 6 of which were consecutive. Max violation of 85 MW occurred on 04/04/2020 at 0005 hrs. Constraint equation violated due to Newport PS being limited by its start-up profile
F_MAIN+NIL_DYN_RREG	Constraint equation violated for 12 consecutive DIs with violation degree of 350 MW occurring for all 12 DIs on 16/04/2020 from 1725 hrs to 1820 hrs. Constraint equation violated due to SCADA failure resulting the EMS receiving zero availability for FCAS regulation.
F_I+RREG_0220	Constraint equation violated for 12 consecutive DIs with violation degree of 220 MW for all DIs. Constraint equation violation occurred due to the same reasons as F_MAIN+NIL_DYN_RREG.
F_I+LREG_0210	Constraint equation violated for 12 consecutive DIs with violation degree of 210 MW. Constraint equation violation occurred due to the same reasons as F_MAIN+NIL_DYN_RREG.
F_TASCAP_RREG_0220	Constraint equation violated for 12 consecutive DIs with violation degree of 170 MW. Constraint equation violation occurred due to the same reasons as F_MAIN+NIL_DYN_RREG.
F_TASCAP_LREG_0210	Constraint equation violated for 12 consecutive DIs with violation degree of 160 MW. Constraint equation violation occurred due to the same reasons as F_MAIN+NIL_DYN_RREG.
F_MAIN++RREG_0220	Constraint equation violated for 12 consecutive DIs with violation degree of 2 MW. Constraint equation violation occurred due to the same reasons as F_MAIN+NIL_DYN_RREG.
N^N-LS_SVC	Constraint equation violation occurred for 10 DIs, 6 of which were consecutive. Max violation of 24.56 MW occurred on 29/04/2020 at 1815 hrs. Constraint equation violation occurred due to competing requirements with import constraint, N_X_MBTE2_B.
V_YENDWF_MAX	Constraint equation violated for 5 DIs with max violation of 1.18 MW occurring on 15/04/2020 at 0730 hrs. Constraint equation violation occurred due to Yendon Wind Farm non-conforming to the limit.
F_T_AUFLS2_R6	Constraint equation violation occurred for 3 DIs on 4/04/2020 at 0045 hrs and 1115 hrs and 5/04/2020 at 1015 hrs. Max violation of 4.19 MW occurred on 5/04/2020 at 1015 hrs. Constraint equation violated due to Tasmania raise 6-second 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)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1937 (161.42)	365.48 (446.02)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	1442 (120.17)	388.15 (446.01)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	943 (78.58)	-69.8 (-114.7)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	913 (76.08)	-84.55 (220.0)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	907 (75.58)	869.41 (1265.51)
S>V_NIL_NIL_RBNW	V-S-MNSP1 Import	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	849 (70.75)	-167.25 (-206.02)
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	722 (60.17)	-52.99 (39.63)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	632 (52.67)	323.55 (446.01)
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	608 (50.67)	40.87 (-446.0)
V^^N_HWSM_1	VIC1-NSW1 Export	Out = Hazelwood to South Morang 500kV line, avoid voltage collapse around Murray for loss of all APD potlines	393 (32.75)	876.54 (1208.25)

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

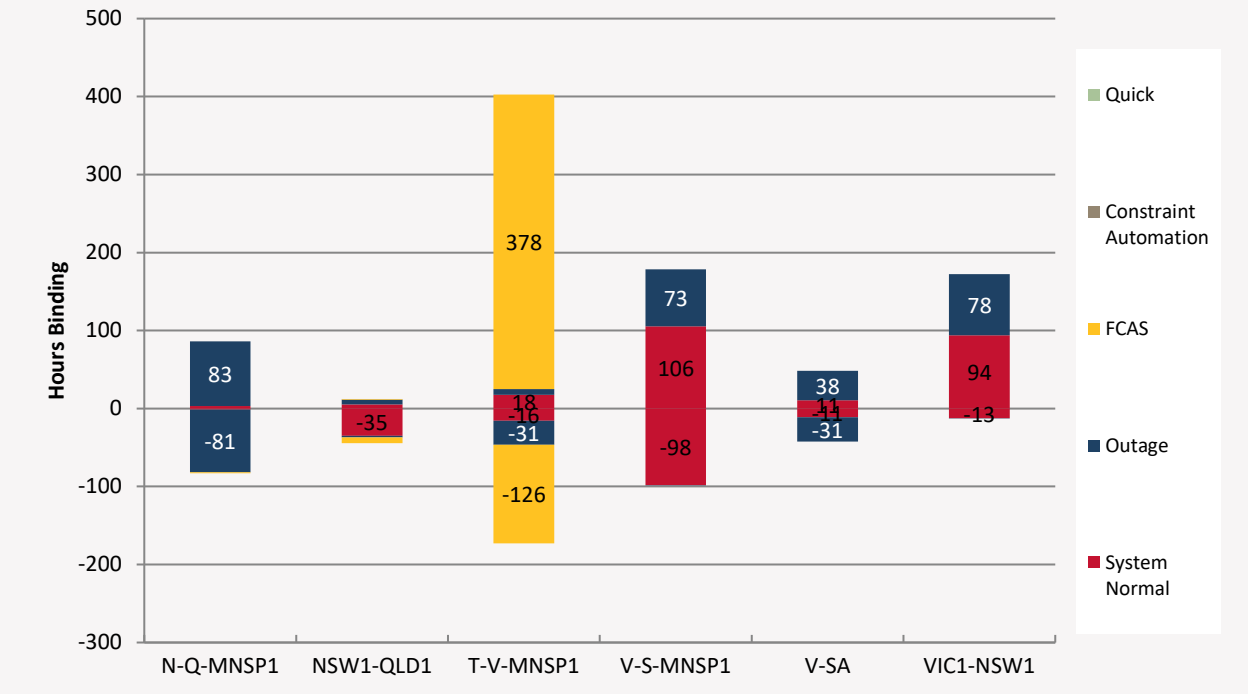
Non-real time constraint automation was not used.

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.

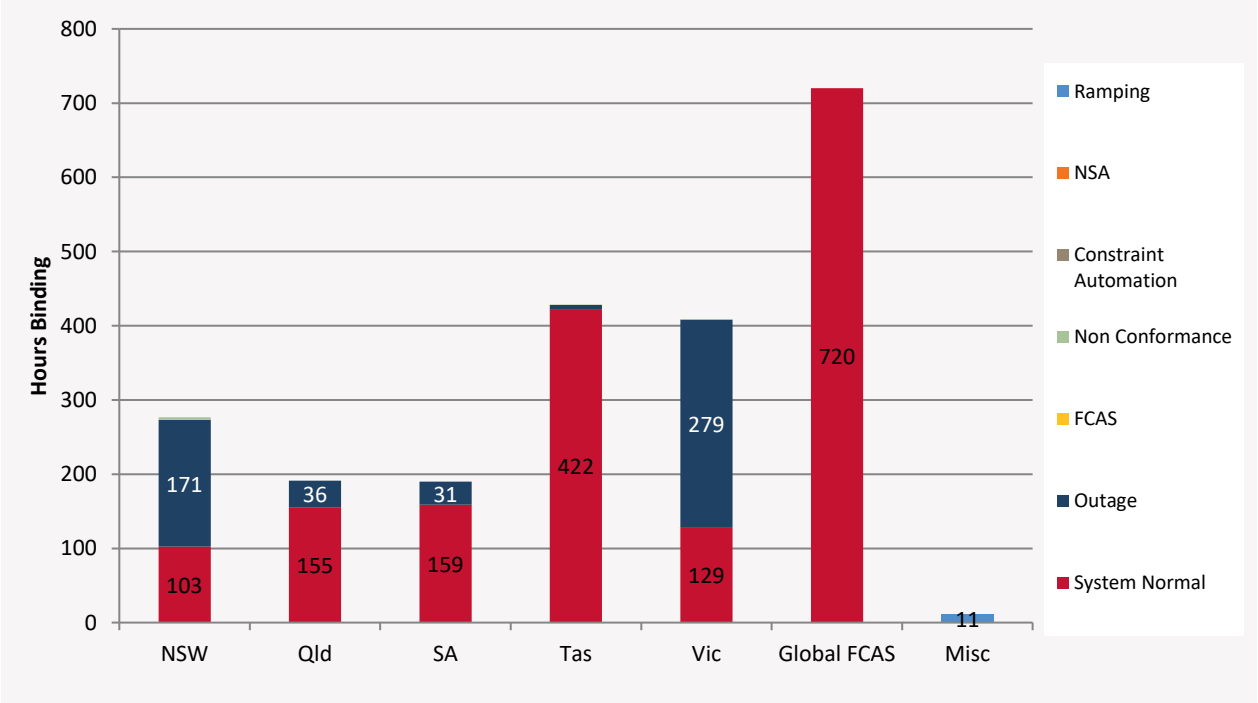
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

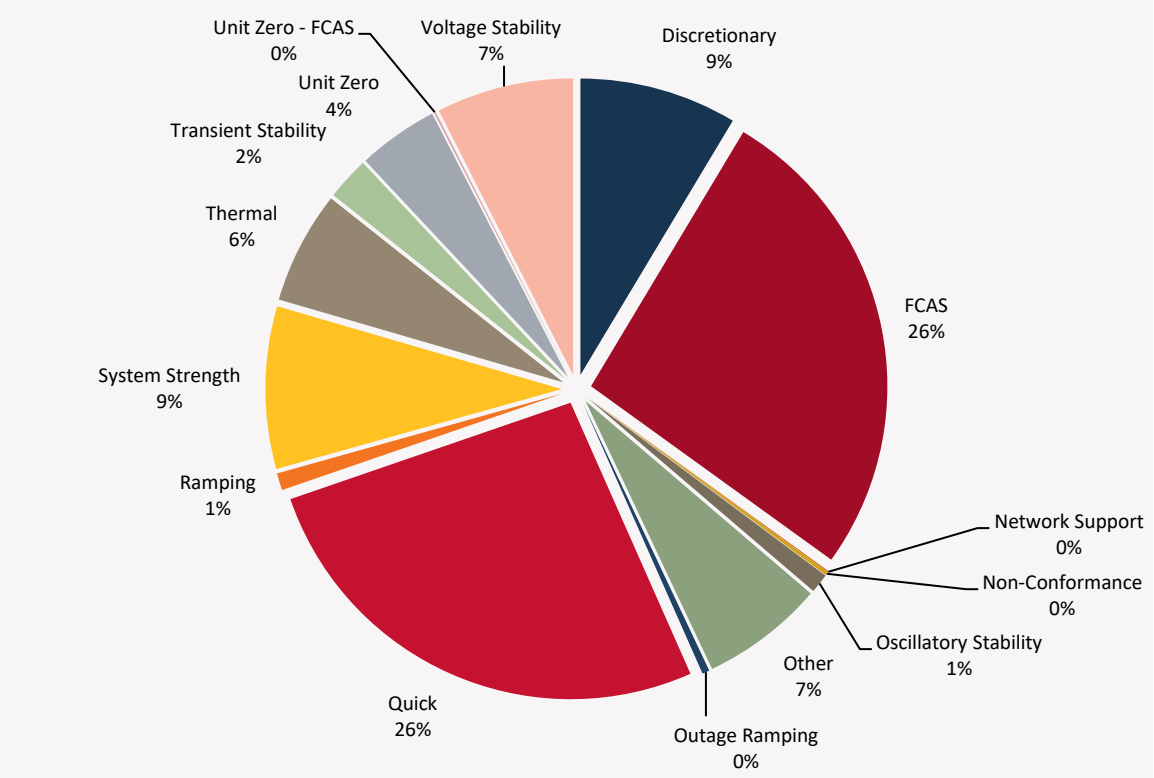
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

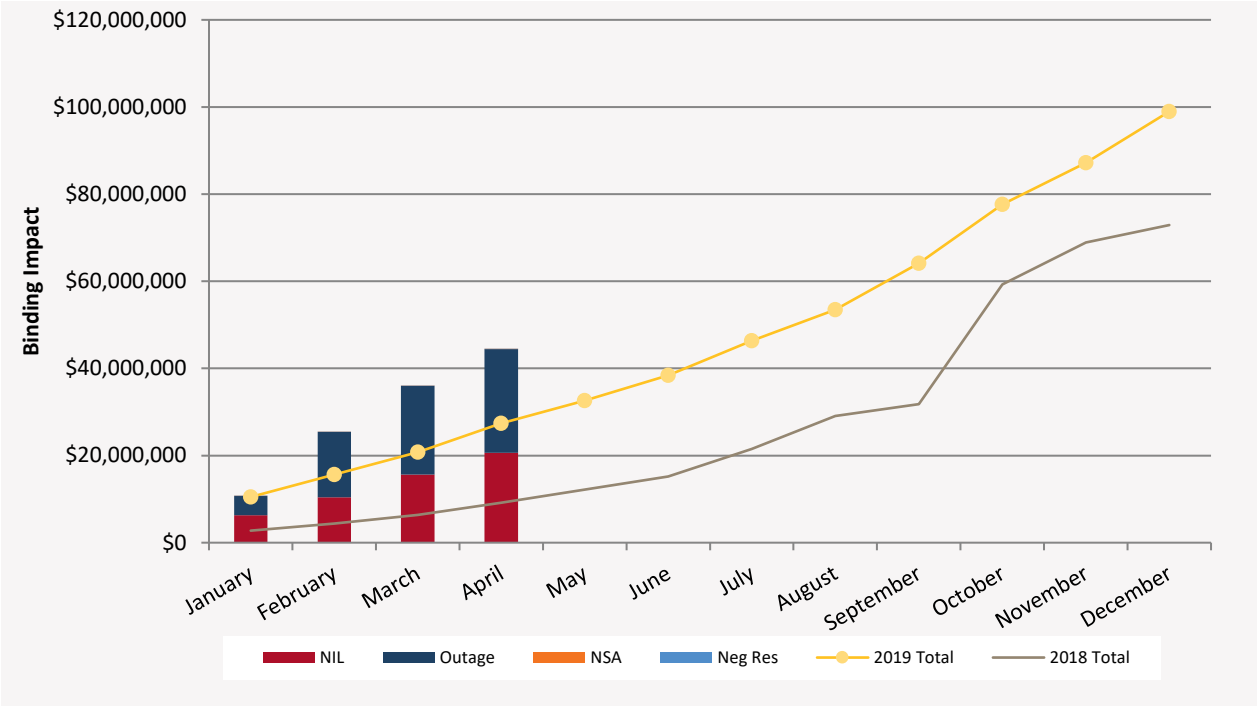
Figure 3 Binding by limit type



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 6 Top 10 largest Dispatch / Pre-dispatch differences

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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	136	37,213% (128.86)	880% (36.13)
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.	67	2,921% (434.69)	176% (109.92)
N_X_MBTE2_A	Out= two Directlink cables, NSW to Qld limit	56	700% (28.7)	77.79% (16.11)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	37	503% (383.51)	91.72% (116.48)
V::N_EPMB_S2	Out = Eildon to Mt Beauty 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV.	9	254% (149.09)	64.46% (78.94)
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	45	205% (151.7)	70.27% (151.7)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	8	183% (196.82)	60.86% (83.92)
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	23	135.11% (139.7)	45.7% (49.32)
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.	223	119.72% (291.22)	26.02% (105.51)
V::N_EPMB_V2	Out = Eildon to Mt Beauty 220kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	19	112.31% (181.66)	37.65% (76.49)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

N^N-LS_SVC: Investigated and no improvement can be made at this stage. This constraint was updated in August 2019 to improve the PD performance.

V::N_HWSM_V2: Investigated and no improvement can be made to the constraint equations at this stage.

N_X_MBTE2_A: 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_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_MURRAWRWF_MAX: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_HWSM_S1: 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 April 2020.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Cherry Tree Wind Farm	28 April 2020	VIC	New Generator
Elaine Wind Farm	7 April 2020	VIC	New Generator

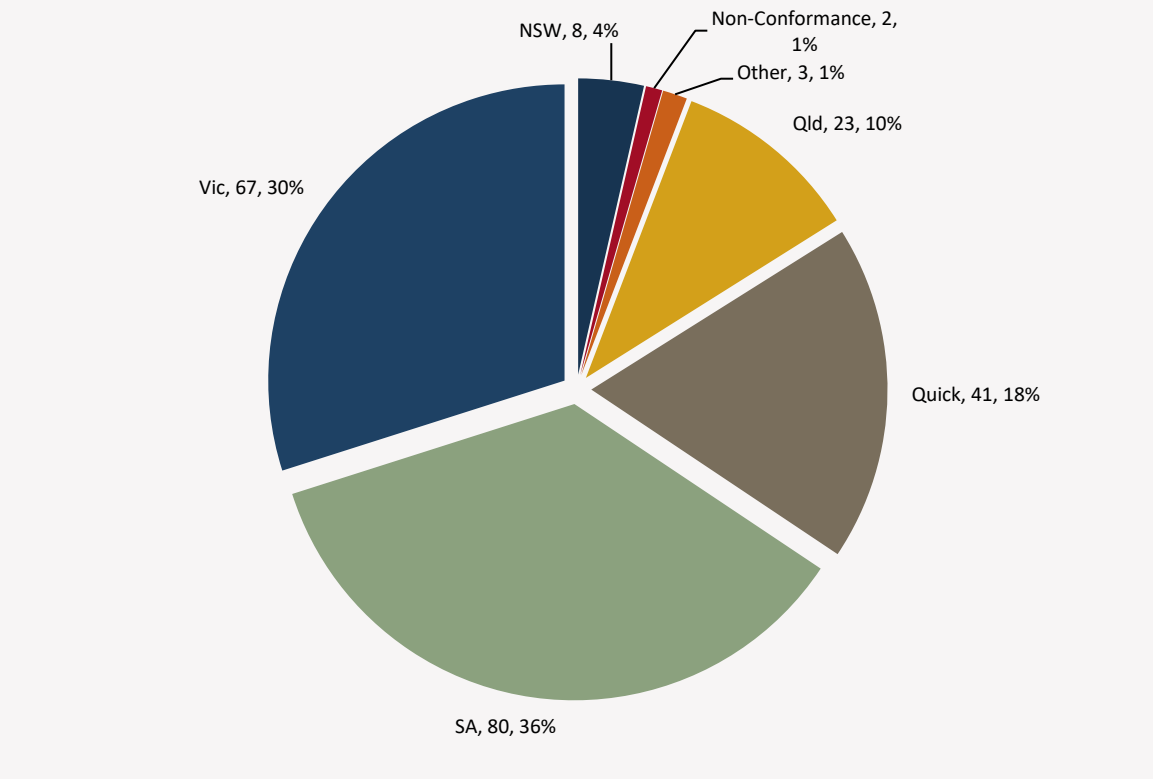
3.1 Constraint Equation Changes

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