AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

March 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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1. Introduction

This report details constraint equation performance and transmission congestion related issues for March 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_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	4139 (344.91)	25/11/2013
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	2523 (210.25)	31/03/2020
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	2398 (199.83)	31/03/2020
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	2045 (170.41)	25/11/2013
N>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	1932 (161.0)	22/01/2020
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	824 (68.66)	15/05/2019
Q^^NIL_QNI_SRAR	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	678 (56.5)	18/06/2019
S>V_NIL_NIL_RBNW	Out = Nil, avoid overloading Robertstown-North West Bend #1 or #2 132kV lines for no contingencies, feedback	619 (51.58)	2/10/2019
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.	610 (50.83)	8/01/2020

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
Q_NIL_STRGTH_MEWF	Out = Nil,100% max capacity(180MW) of Mt Emerald WF if (Stan+Cal+Glad) >=10+Stan>=3+CalB>=1+CalC>=1+Glad>=4 and Kar=4+Bar=2,80%(Kar=4+Bar=1 or Kar>=2+TVGT>=1),70%(Kar=4+Bar=0 or Kar=2+Bar=1) Zero otherwise	524 (43.66)	19/03/2020

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
N>N-NIL_CLDP_1	Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback	2,030,968	22/01/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	825,191	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.	618,404	8/01/2020
Q_NIL_STRGTH_MEWF	Out = Nil,100% max capacity(180MW) of Mt Emerald WF if (Stan+Cal+Glad) >=10+Stan>=3+CalB>=1+CalC>=1+Glad>=4 and Kar=4+Bar=2,80%(Kar=4+Bar=1 or Kar>=2+TVGT>=1),70%(Kar=4+Bar=0 or Kar=2+Bar=1) Zero otherwise	544,051	19/03/2020
Q_MEWF1_ZERO	Mt Emerald Wind Farm upper limit of 0 MW	525,017	19/07/2018
Q_NIL_STRGTH_HAUSF	Out = Nil,100% max capacity(100MW) of Haughton SF if (Stan+Cal+Glad) >=10+Stan>=3+CalB>=1+CalC>=1+Glad>=4 and Kar=4+Bar=2,80%(Kar=4+Bar=1 or Kar>=2+TVGT>=1),70%(Kar=4+Bar=0 or Kar=2+Bar=1) Zero otherwise	428,194	19/03/2020
Q_HAUGHTSF1_ZERO	Haughton Solar Farm upper limit of 0MW	381,817	14/11/2018
SA_ISLE_HPR_HIGH_SOC	Out = SA / ESTN separation between Moorabool and Mortlake/Haunted Gully, upper limit on Hornsdale battery of 2 MW, except when state of charge is above 70%	275,808	6/02/2020

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
F_S_HPRL_LREG-5MW	Out= NIL, Hornsdale Battery (Load Component) LREG Requirement <= 5MW	230,203	13/02/2020
F_S++TIB4_R6_1	Raise 6 sec Service Requirement for SA Generation Event, where Torrens Island B unit 4 is the largest generation risk in SA, Segment 1	184,561	14/02/2020

2.3 Top 10 violating constraint equations

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

Table 3 Top 10 violating constraint equations

Table 1 – Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
F_S+PPT_R6_1	Raise 6 sec Service Requirement for SA Generation Event, where Pelican Point GT11 or GT12 or ST is the largest generation risk in SA, Segment 1	28 (2.33)	14/02/2020
F_S+TL_L6_OD	Lower 6 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load	26 (2.16)	14/02/2020
F_S+PPT_R6_2	Raise 6 sec Service Requirement for SA Generation Event, where Pelican Point GT11 or GT12 or ST is the largest generation risk in SA, Segment 2	18 (1.5)	14/02/2020
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	17 (1.41)	21/12/2018
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	10 (0.83)	4/05/2018
F_S_HPRL_LREG-5MW	Out= NIL, Hornsdale Battery (Load Component) LREG Requirement <= 5MW	10 (0.83)	13/02/2020
F_S+TL_L6_0150	Lower 6 sec Service Requirement for a 150 MW SA Network (Load) Event	8 (0.66)	14/02/2020
F_S+TG_R6_150	Raise 6 sec Service Requirement for a 150 MW SA Generation Event	8 (0.66)	14/02/2020
F_S+TL_L60_0150	Lower 60 sec Service Requirement for a 150 MW SA Network (Load) Event	8 (0.66)	14/02/2020
F_S+TL_L60_OD	Lower 60 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load	8 (0.66)	14/02/2020

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Table 2 – Reasons for Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description
F_S+PPT_R6_1	Constraint equation violated for 28 DIs, 15 of which were consecutive. Max violation of 61.65 MW occurring on 02/03/2020 at 1445 hrs. Constraint equation violated due to South Australia raise 6 second service being less than the requirement. This was a result of the separation event between Victoria and South Australia
F_S+TL_L6_OD	Constraint equation violated for 26 consecutive DIs with max violation of 97.2 MW occurring on 02/03/2020 at 1225 hrs. Constraint equation violation is due to South Australia lower 6 second service being less than the requirement. This was a result of the separation event between Victoria and South Australia.
F_S+PPT_R6_2	Constraint equation violated for 18 non-consecutive DIs with max violation of 154.53 MW occurring on 02/03/2020 at 1325 hrs. Constraint equation violatied due to the same reason as F_S+PPT_R6_1.
NSA_V_NPSD_100	Constraint equation violated for 17 non-consecutive DIs with max violation of 68.13 MW occurring on 01/03/2020 0105 hrs. Constraint equation violated due to Newport PS being limited by its start-up profile.
F_T_AUFLS2_R6	Constraint equation violated for 10 DIs, 6 of which were consecutive. Max violation of 27.62 MW occurred on 19/03/2020 at 0915 hrs. Constraint equation violated due to Tasmania raise 6 second service being less than the requirement.
F_S_HPRL_LREG-5MW	Constraint equation violated for 10 DIs, where 9 of which were consecutive. Max violation of 21 MW occurred on 02/03/2020 at 1250 hrs. Constraint equation violated due to non-conformance of the Hornsdale battery.
F_S+TL_L6_0150	Constraint equation violated for 8 consecutive DIs with max violation of 222.75 MW occurring at 1225 hrs on 02/03/2020. Constraint equation violated due to the same reason as F_S+TL_L6_OD.
F_S+TG_R6_150	Constraint equation violated for 8 consecutive DIs. Max violation of 182.25 MW occurred on 02/03/2020 at 1220 hrs and 1225 hrs. Constraint equation violated due to the same reason as F_S+PPT_R6_1.
F_S+TL_L60_0150	Constraint equation violated for 8 consecutive DIs. with max violation of 51.44 MW occurring on 02/03/2020 at 1225 hrs. Constraint equation violated due to South Australia lower 60 second service being less than the requirement. This was a result of the separation event between Victoria and South Australia.
F_S+TL_L60_OD	Constraint equation violated for 8 non-consecutive DIs with max violation of 48.57 MW occurring on 02/03/2020 at 1415 hrs. Constraint equation violated due to the same reason as F_S+TL_L60_0150.

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)
N_X_MBTE_3B	N-Q-MNSP1 Import	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	4139 (344.92)	-30.02 (-61.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
N_X_MBTE_3A	N-Q-MNSP1 Export	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	2043 (170.25)	-34.88 (-8.3)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1548 (129.0)	206.59 (446.01)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	818 (68.17)	917.53 (1263.53)
V^^N_NIL_1	V-S-MNSP1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	809 (67.42)	-108.67 (220.0)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	766 (63.83)	126.32 (446.01)
F_MAIN++NIL_MG_R5	T-V-MNSP1 Export	Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS	720 (60.0)	179.72 (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	715 (59.58)	-242.73 (-446.0)
Q^^NIL_QNI_SRAR	NSW1-QLD1 Import	Out = Nil, limit QLD to NSW on QNI to avoid voltage instability on trip of Sapphire - Armidale (8E) 330 kV line	678 (56.5)	-990.18 (-1121.26)
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	619 (51.58)	-157.06 (-188.95)

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

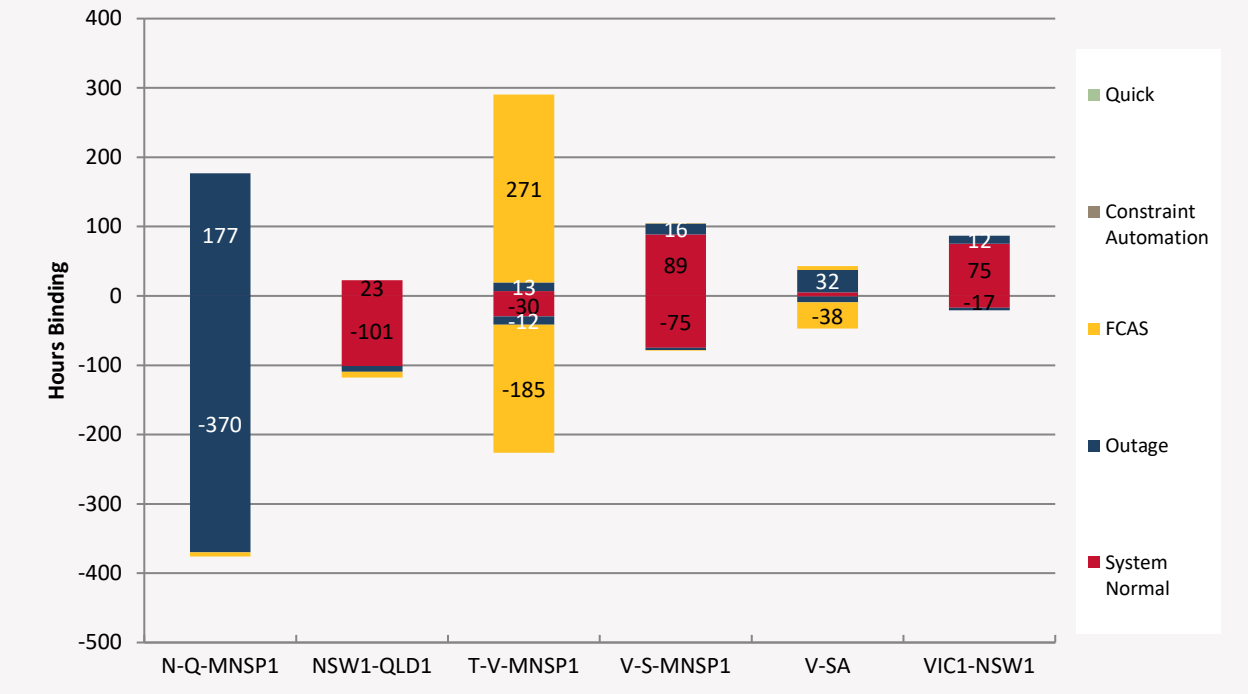
Non-real time constraint automation was not used.

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.

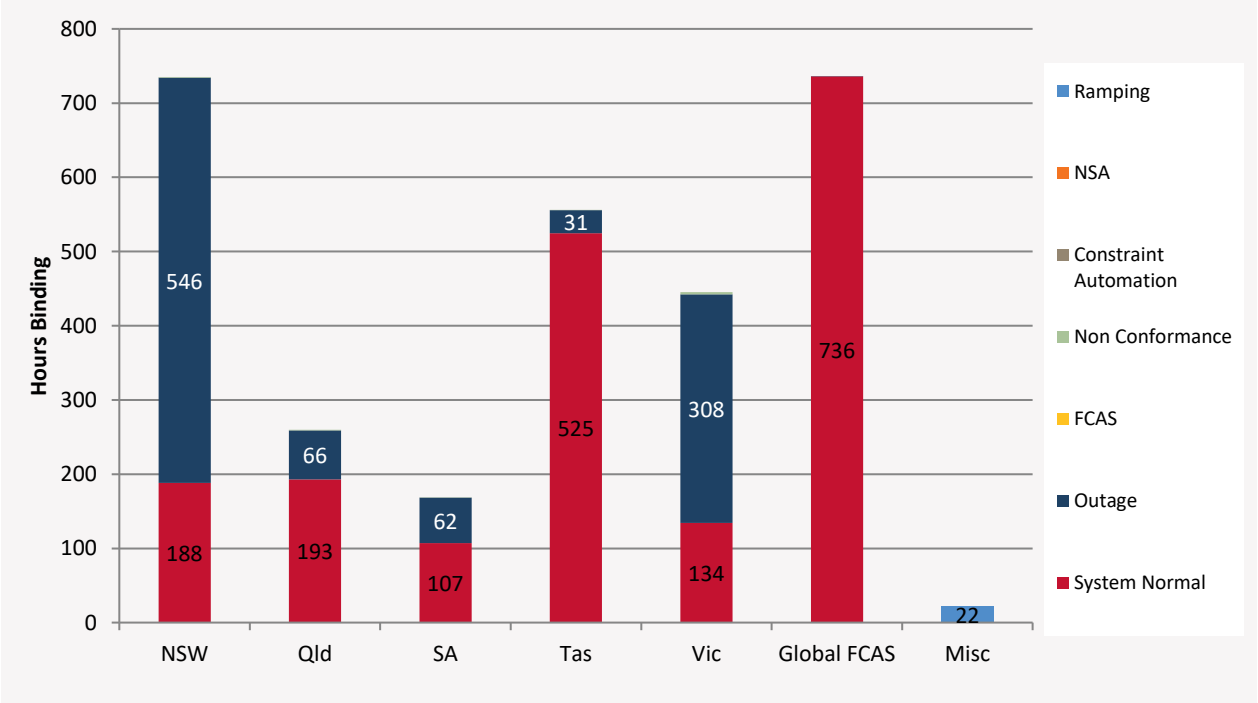
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

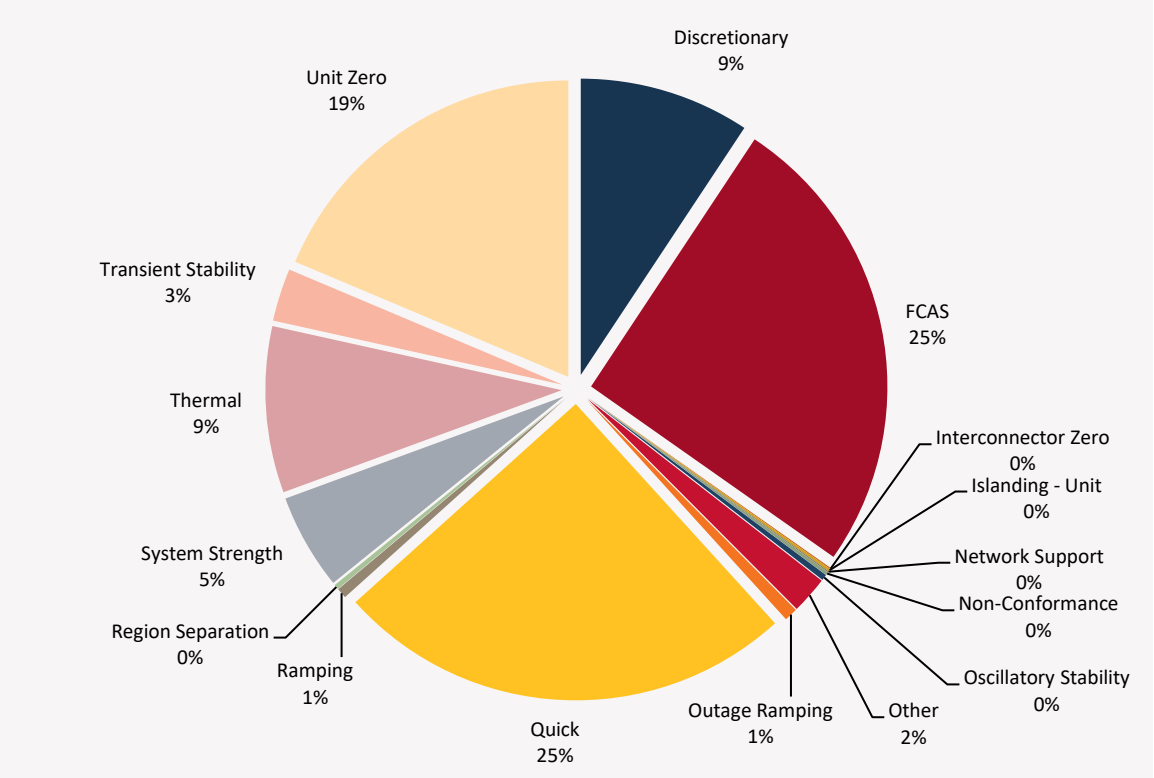
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

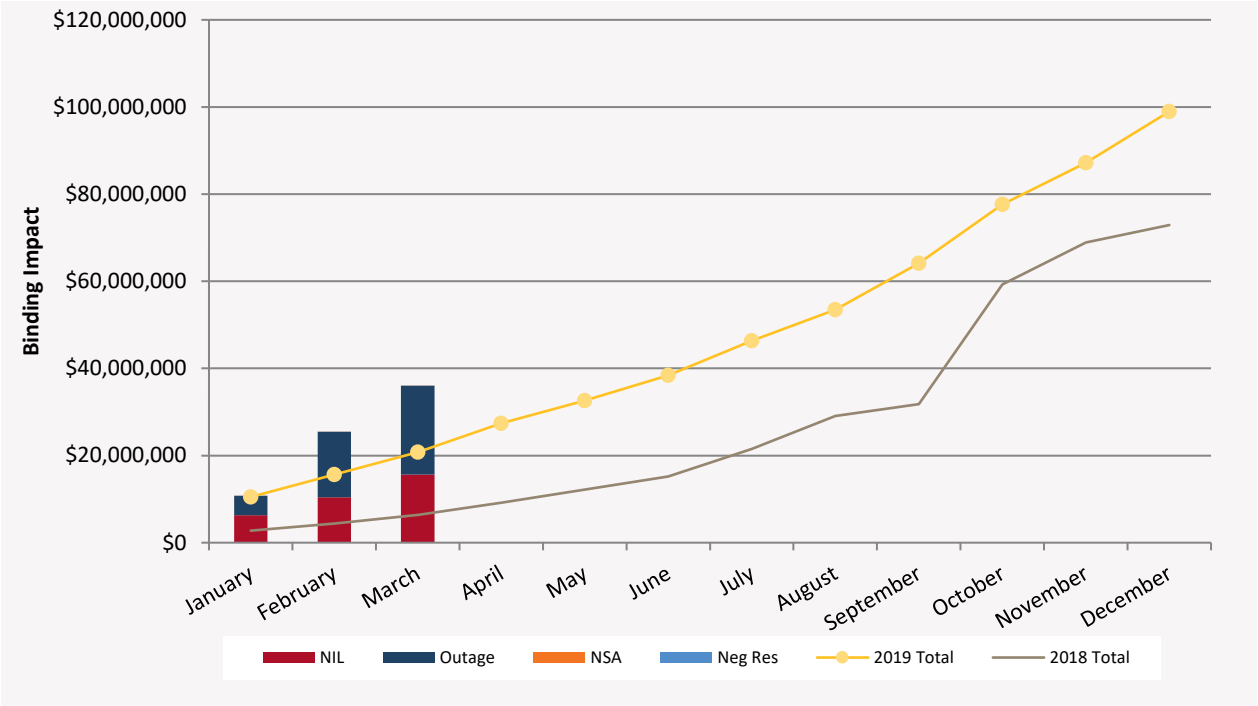
Figure 3 Binding by limit type



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
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.	23	2,909% (232.37)	179% (112.46)
V_MLMO_VS_LB_CAN_50	Out = Moorabool to Mortlake 500 kV line, TRTS 500kV centre CB fail timer set to zero, No.2 HYTS line CB at APD OPEN, limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement. Constraint swamp out if MOPS/DUNDWF generating.	49	1,883% (90.82)	156% (25.43)
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.	25	646% (179.95)	77.97% (75.59)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	65	604% (345.02)	42.75% (93.74)
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	51	205% (151.7)	94.22% (151.7)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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]	10	170% (120.49)	100.59% (90.49)
V_YENDWF_MAX	Limit MW output of Yendon wind farm to hold point levels during day/night	24	145.24% (61.)	62.8% (61.)
N_X_MBTE_3A	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	426	127.37% (32.8)	22.9% (8.17)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	720	117.6% (32.8)	26.39% (9.39)
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	12	96.28% (93.8)	55.35% (49.3)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

V_MLMO_VS_LB_CAN_50: Investigated and no improvement can be made to the constraint equation at this stage.

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

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.

S>NIL_HUWT_STBG2: Investigated and no improvement can be made to the constraint equation at this stage.

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

N_X_MBTE_3A: 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.

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.

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

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 March 2020.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Dundonnell Wind Farm 1	10 March 2020	VIC	New Generator
Dundonnell Wind Farm 3	10 March 2020	VIC	New Generator
Dundonnell Wind Farm 2	10 March 2020	VIC	New Generator
Bomen Solar Farm	17 March 2020	NSW	New Generator

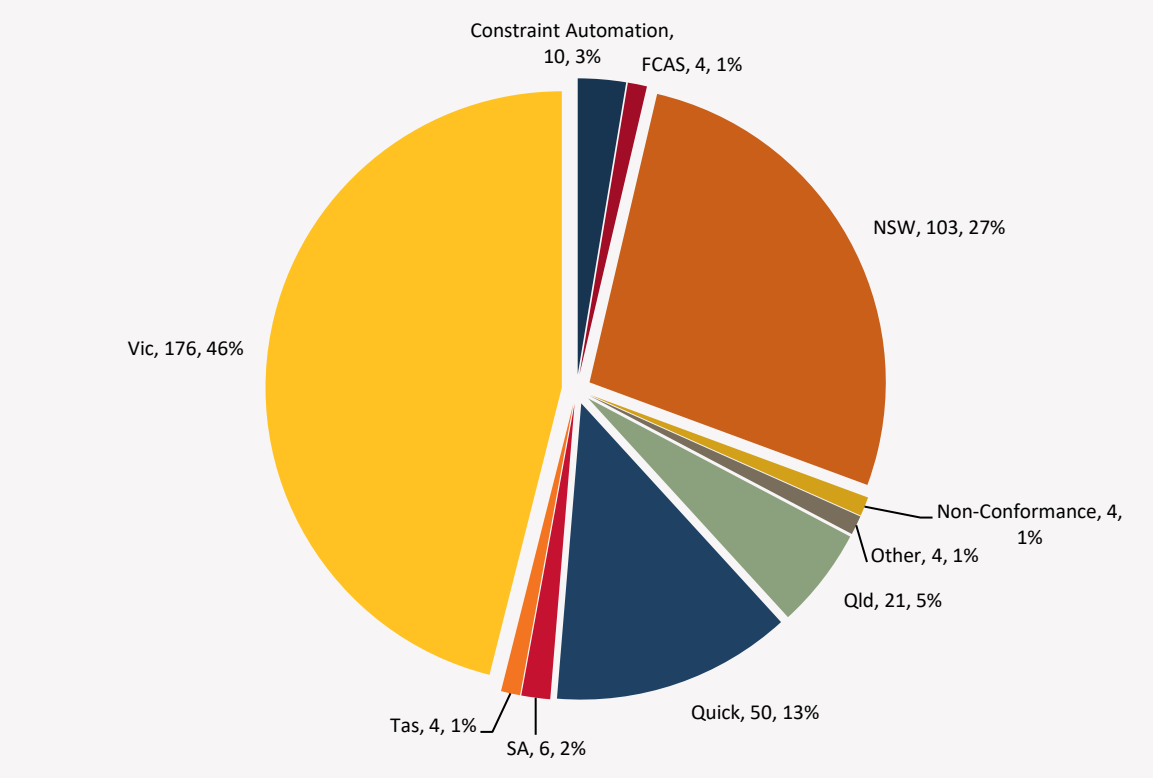
3.1 Constraint Equation Changes

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