AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

March 2021

A report for the National Electricity Market

Important notice

PURPOSE

This publication has been prepared by AEMO to provide information about constraint equation performance and related issues, as at the date of publication.

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1. Introduction

This report details constraint equation performance and transmission congestion related issues for March 2021. Included are investigations of violating constraint equations, usage of the constraint automation and performance of Pre-dispatch constraint equations. Transmission and generation changes are also detailed along with the number of constraint equation changes.

2. Constraint Equation Performance

2.1 Top 10 binding constraint equations

A constraint equation is binding when the power system flows managed by it have reached the applicable thermal or stability limit or the constraint equation is setting a Frequency Control Ancillary Service (FCAS) requirement. Normally there is one constraint equation setting the FCAS requirement for each of the eight services at any time. This leads to many more hours of binding for FCAS constraint equations - as such these have been excluded from the following table.

Table 1 Top 10 binding network constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
S>NIL_MHNW1_MHNW2	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	2608 (217.33)	29/09/2020
N^^N_NIL_2	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	1420 (118.33)	31/03/2021
T_MRWF_FOS	Limit Musselroe wind farm due to upper limit on Tasmanian generator events. Limit is 153 MW (effective 144 MW at the connection point at Derby)	1386 (115.5)	1/01/2020
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 generating.	1385 (115.41)	12/03/2021
V_S_NIL_ROCOF	Out = NIL, limit VIC to SA Heywood interconnection flow to prevent Rate of Change of Frequency exceeding 2 Hz/sec in SA immediately following loss of Heywood interconnector. [NOTE: Switches based on ON/OFF status of Dalry Battery in Load Mode)]	1140 (95.0)	9/10/2020
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	888 (74.0)	11/02/2021
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	863 (71.91)	31/03/2021

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
SA_ISLE_STRENGTH_BU	Maximum limit (130 MW) for Bungala Solar Farm for system strength requirements when SA is at risk of separation or when islanded.	784 (65.33)	13/09/2019
N>N-NIL_9R4_99A	Out= Nil, avoid O/L Finley to Mulwala 132kV line (9R4) on trip of Finley to Uranquinty (99A) line, Feedback	744 (62.0)	31/03/2021
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.	684 (57.0)	26/03/2020

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_2	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	1,232,423	31/03/2021
S>NIL_MHNW1_MHNW2	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	796,461	29/09/2020
SA_ISLE_STRENGTH_BU	Maximum limit (130 MW) for Bungala Solar Farm for system strength requirements when SA is at risk of separation or when islanded.	768,773	13/09/2019
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 generating.	737,949	12/03/2021
N>N-NIL_9R4_99A	Out= Nil, avoid O/L Finley to Mulwala 132kV line (9R4) on trip of Finley to Uranquinty (99A) line, Feedback	621,272	31/03/2021
F_S+MLMO_TL_L60	Out= Moorabool to Mortlake 500kV line, SA Lower 60 sec requirement for loss of Heywood to Tarrone to Haunted Gully to Moorabool 500kV lines	603,407	18/03/2021
V>V_NIL_17	Out = NIL, prevent pre-contingent overload of Wemen 220/66 kV txfmr, flow from 66 kV to 220 kV, feedback	433,321	29/09/2020

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
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)	417,983	1/01/2020
Q_STR_32282_HASF	Limit 75% to Haughton SF if Stan>=3+Cal>=2+Glad>=2+ (Stan+Cal+Glad) >=8, Kareeya>=2, NQLD>450&470(AVG),Ross_FN>250&270(AVG). Zero otherwise. .	320,910	27/01/2021
N>>N-NIL_94T_947	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Wellington to Orange North (947), Feedback	269,029	30/03/2021

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
N_BKHSF_44INV	Limit Broken Hill Solar Farm upper limit to 0 MW if number of inverter available exceed 44. Constraint swamp out if number of inverter available not exceed 44. This is to manage voltage oscillation. DS only	6 (0.5)	11/08/2020
N_BROKENH1_0INV	Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only	6 (0.5)	22/12/2020
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	5 (0.41)	21/12/2018
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	5 (0.41)	4/05/2018
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	5 (0.41)	23/12/2020
S_TIPSB_270	Out = NIL, Loss of Torrens Island A Power Station declared credible as a single credible contingency, discretionary upper limit for TIPSB1+TIPSB2+TIPSB3+TIPSB4 <= 270 MW	4 (0.33)	18/05/2020
NC_N_VP6	Non Conformance Constraint for Vales Point VP6 Power Station	3 (0.25)	21/08/2013
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	3 (0.25)	2/12/2016
N^^Q_NIL_B1	Out= Nil, avoid Voltage Collapse on loss of Kogan Creek	1 (0.08)	6/12/2017
T_T_FASH_2_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, limit Mackintosh >= 90% of West Coast load	1 (0.08)	16/02/2018

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
N_BKHSF_44INV	Constraint equation violated for 6 non-consecutive DIs on 17/03/2021 with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit.
N_BROKENH1_0INV	Constraint equation violated for 6 non-consecutive DIs on 17/03/2021 with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit.
NSA_V_NPSD_100	Constraint equation violated for 5 DIs on 21/03/2021 from 0135 hrs to 0155 hrs with max violation of 58.81 MW occurring at 0135 hrs. Constraint equation violation occurred due to Newport PS being limited by its start-up profile.
F_T_AUFLS2_R6	Constraint equation violated for 5 DIs on 01/03/2021, 20/03/2021 and 25/03/2021 with max violation of 12.58 MW occurring on 25/03/2021 at 0910 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
F_T+NIL_WF_TG_R6	Constraint equation violated for 5 DIs on 04/03/2021, 14/03/2021, 20/03/2021 and 25/03/2021 with max violation 8.73 occurring on 25/03/2021 at 0325 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
S_TIPSB_270	Constraint equation violated for 4 DIs on 12/03/2021 with max violation of 146.84 MW occurring at 1755 hrs. Constraint equation violation occurred due constraint equation being invoked without ramping.
NC_N_VP6	Constraint equation violated for 3 DIs on 31/03/2021 at 1835 hrs, 1840 hrs and 1925 hrs with max violation of 15 MW occurring at 1835 hrs and 1840 hrs. Constraint equation violation occurred due to Vales Point VP6 non-conforming.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 3 DIs on 01/03/2021 at 1050 hrs, 05/03/2021 at 1025 hrs and 20/03/2021 at 0935 hrs with max violation of 5.35 MW occurring on 01/03/2021 at 1050 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
N^^Q_NIL_B1	Constraint equation violated for 1 DI on 08/03/2021 at 1735 hrs with violation degree 64.24 MW. Constraint equation violation occurred due to competing requirements with the import limits which were set by QNTE_ROC and I_QNI_ONE_PHASE_N-2.
T_T_FASH_2_N-2	Constraint equation violated for 1 DI on 02/03/2021 at 2210 hrs with violation degree 34.12 MW. Constraint equation violation occurred due to constraint equation being invoked without ramping.

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)
S>NIL_MHNW1_MHNW2	V-S-MNSP1 Export	Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback	2461 (205.08)	160.5 (184.76)

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	1555 (129.58)	83.16 (446.01)
V_S_NIL_ROCOF	V-SA Export	Out = NIL, limit VIC to SA Heywood interconnection flow to prevent Rate of Change of Frequency exceeding 2 Hz/sec in SA immediately following loss of Heywood interconnector. [NOTE: Switches based on ON/OFF status of Dalry Battery in Load Mode)]	1137 (94.75)	424.61 (526.09)
V_MLMO_VS_LB_CAN_50	V-SA Export	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 generating.	1130 (94.17)	6.57 (50.64)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1100 (91.67)	-50.03 (446.0)
N^^N_NIL_2	V-S-MNSP1 Import	Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback	1029 (85.75)	124.88 (-115.1)
V^^N_NIL_1	VIC1-NSW1 Export	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	859 (71.58)	873.31 (1264.26)
N^^N_NIL_3	VIC1-NSW1 Export	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	834 (69.5)	358.6 (1018.17)
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	779 (64.92)	-294.25 (-446.0)
F_S+MLMO_TL_L60	V-SA Import	Out= Moorabool to Mortlake 500kV line, SA Lower 60 sec requirement for loss of Heywood to Tarrone to Haunted Gully to Moorabool 500kV lines	683 (56.92)	2.41 (-139.04)

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

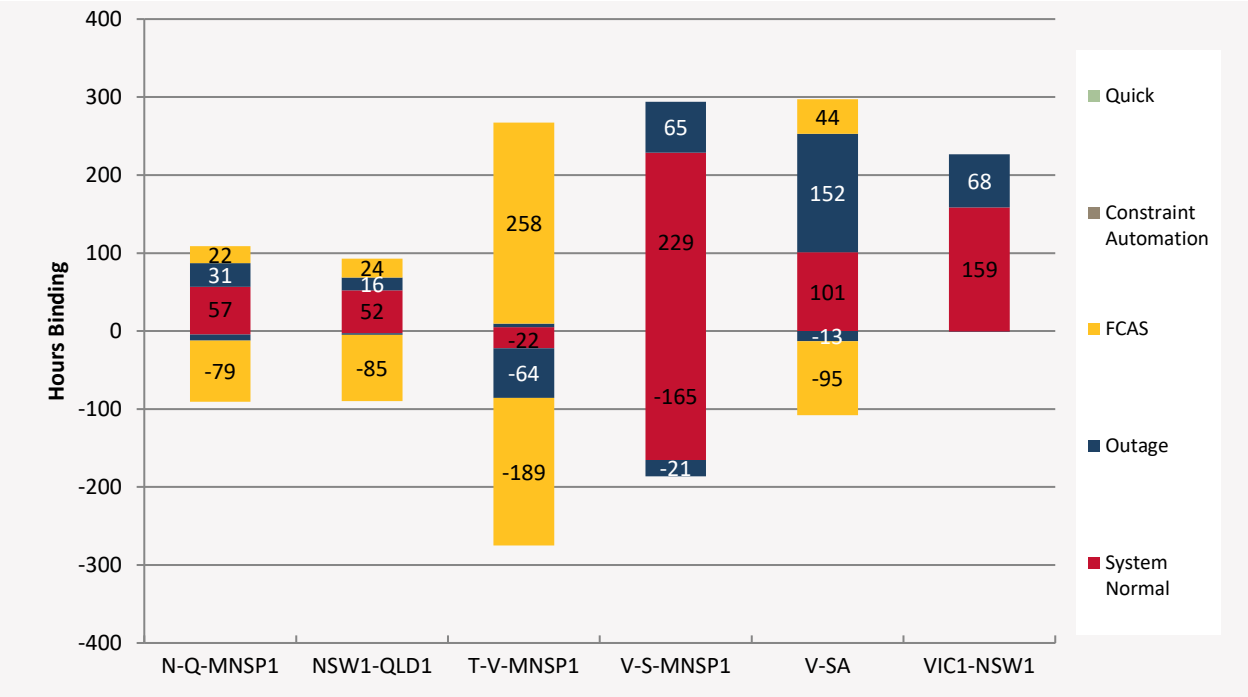
Non-real time constraint automation was not used.

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.

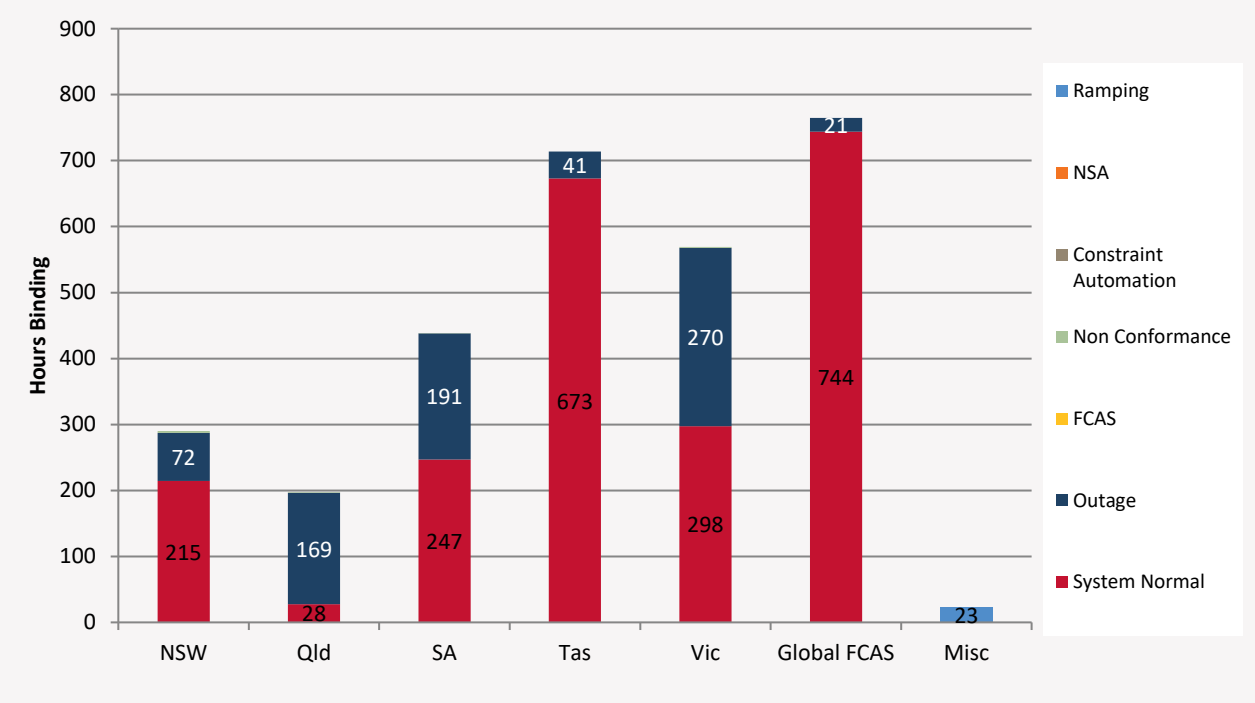
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

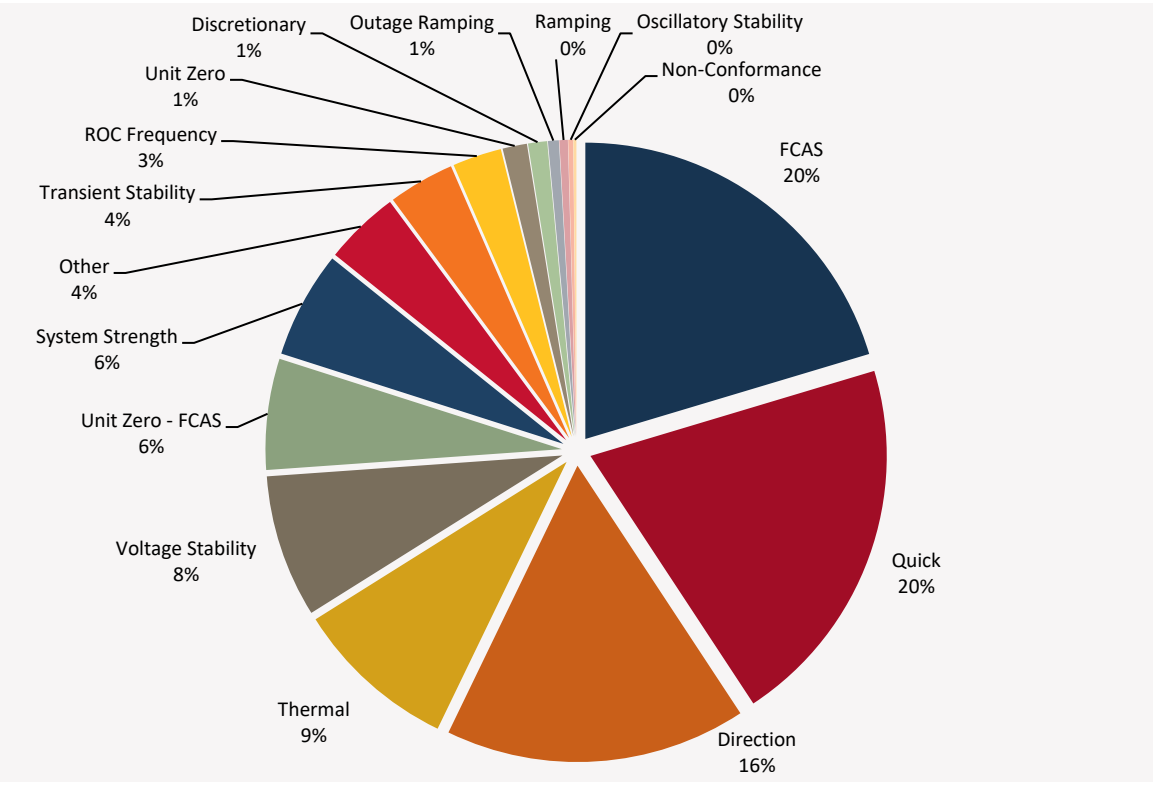
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

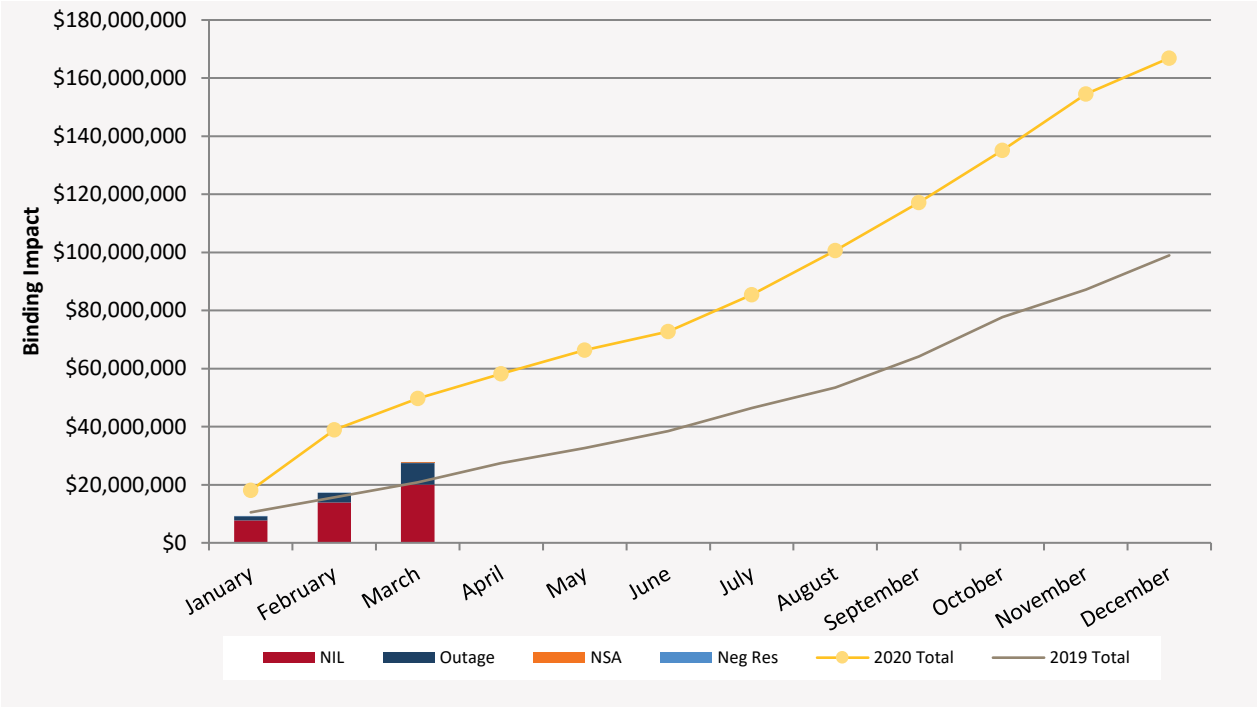
Figure 3 Binding by limit type



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_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 generating.	244	4,728% (77.44)	103.5% (11.76)
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	113	1,876% (9,494)	60.92% (193.73)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
	for double-circuit loss of Heywood IC.Note: Constraint is swamped if UFLS blocks >= 1000 MW.			
V::N_MLTX_S1	Out = Moorabool Transformer 500/200kV, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 220 kV.	7	1,074% (73.88)	370% (46.)
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.	3	811% (118.22)	496% (92.94)
V::N_ROSM_V2	Out = Rowville to South Morang 500kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, VIC accelerates, Yallourn W G1 on 500 kV.	3	809% (114.31)	298% (86.05)
V::N_MLTX_V1	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 220 kV.	18	793% (141.23)	123.81% (54.61)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	143	382% (337.6)	16.98% (48.52)
V>V_RCTS_TX1B_1	Out= Red Cliffs 1B 220/66kV transformer, avoid O/L Red Cliffs 2B 66/220kV transformer on trip of Red Cliffs 3A transformer, Feedback	35	296% (74.11)	146.1% (36.81)
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]	22	201% (87.74)	83.9% (59.98)
V_VS_LB_CAN_50	Limit Heywood + Lake Bonney WF + Canunda WF <= 50 MW for system strength requirement when SA is at risk of separation.	58	200% (30.2)	35.86% (9.02)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V_MLMO_VS_LB_CAN_50: 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.

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>V_RCTS_TX1B_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_VS_LB_CAN_50: 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 March 2021.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Winton Solar Farm	30 March 2021	VIC1	New Generator

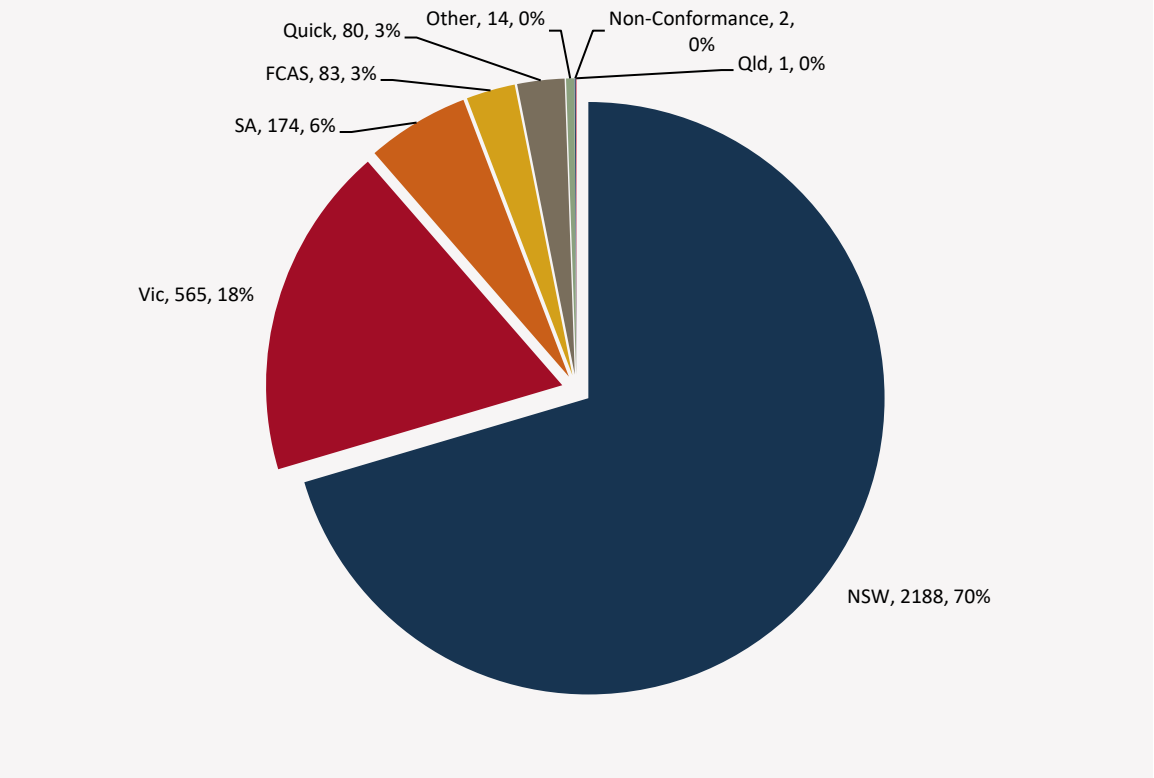
3.1 Constraint Equation Changes

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