AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

November 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 November 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
Q>SSRV_M020/3	Out= Nil, Limit Susan River to the continuous ratings of Feeder M020/3 Susan River to T section 66kV line, Feedback	1820 (151.66)	2/10/2020
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	1220 (101.66)	25/11/2013
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 Table 7 of SO_OG_NEM_62	1014 (84.5)	26/11/2020
Q>NIL_COLNVSF1	Out = Nil, Limit Collinsville Solar Farm to thermal rating of Powerlink's RMU	945 (78.75)	5/11/2019
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	918 (76.5)	20/12/2016
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)	861 (71.75)	1/01/2020
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 Table 7 of SO_OG_NEM_62	843 (70.25)	26/11/2020
V>V_NIL_17	Out = NIL, prevent pre-contingent overload of Wemen 220/66 kV txfmr, flow from 66 kV to 220 kV, feedback	808 (67.33)	29/09/2020

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V_BANNERTSF_FLT_25	Limit Bannerton Solar Farm upper limit to 25 MW to manage post contingent voltage oscillation	767 (63.91)	4/09/2019
V_KARADSF_FLT_25	Limit Karadoc solar farm upper limit to 25 MW to manage post contingent voltage oscillation	752 (62.66)	29/08/2019

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
Q>SSRV_M020/3	Out= Nil, Limit Susan River to the continuous ratings of Feeder M020/3 Susan River to T section 66kV line, Feedback	1,872,909	2/10/2020
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 Table 7 of SO_OG_NEM_62	988,468	26/11/2020
Q>NIL_COLNVSF1	Out = Nil, Limit Collinsville Solar Farm to thermal rating of Powerlink's RMU	918,701	5/11/2019
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 Table 7 of SO_OG_NEM_62	833,652	26/11/2020
V>V_NIL_17	Out = NIL, prevent pre-contingent overload of Wemen 220/66 kV txfmr, flow from 66 kV to 220 kV, feedback	806,040	29/09/2020
V_BANNERTSF_FLT_25	Limit Bannerton Solar Farm upper limit to 25 MW to manage post contingent voltage oscillation	797,553	4/09/2019
V_KARADSF_FLT_25	Limit Karadoc solar farm upper limit to 25 MW to manage post contingent voltage oscillation	776,226	29/08/2019
V_WEMENSF_FLT_25	Limit Wemen Solar Farm upper limit to 25 MW to manage post contingent voltage oscillation	662,686	4/09/2019

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_LIMOSF2_FLT_25	Limit Limondale 2 solar farm upper limit to 25 MW to manage post contingent voltage oscillation	656,286	21/08/2020
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.	648,954	19/08/2020

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

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	24 (2.0)	21/12/2018
NRM_QLD1_NSW1	Negative Residue Management constraint for QLD to NSW flow	19 (1.58)	23/09/2020
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 line, Basslink unable to transfer FCAS	14 (1.16)	12/04/2016
F_T_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	7 (0.58)	4/05/2018
N_FINLYSF_FLT_30	Limit Finley solar farm upper limit to 30 MW to manage post contingent voltage oscillation	6 (0.5)	23/11/2020
N_DARLSF_FLT_80	Limit Darlington Pt Solar Farm upper limit to 80 MW to manage post contingent voltage oscillation	4 (0.33)	30/10/2020
Q>SSRV_M020/3	Out= Nil, Limit Susan River to the continuous ratings of Feeder M020/3 Susan River to T section 66kV line, Feedback	4 (0.33)	2/10/2020
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	4 (0.33)	11/08/2020
F_Q++MUTW_L60	Out = Muswellbrook to Tamworth (88) line, Qld Lower 60 sec Requirement	3 (0.25)	10/09/2019
F_Q++MUTW_L6	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	3 (0.25)	10/09/2019

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 violated for 24 non-consecutive DIs on 08/11/2020, 14/11/2020, 15/11/2020, 16/11/2020 and 21/11/2020 with max violation of 85 MW occurring on 08/11/2020 at 0105 hrs. Constraint equation violation occurred due to Newport PS being limited by its start-up profile.
NRM_QLD1_NSW1	Constraint equation violated for 19 non-consecutive DIs 16 of which were consecutive on 17/11/2020 from 1325 to 1440 hrs. The max violation of 220.532 MW occurred on 17/11/2020 at 1335 hrs. Constraint equation violation occurred due to competing requirements with the export limit which were set by N>N-ARCH_87_TE_C1, Q>>NIL_CLWU_RGLC.
F_T+NIL_WF_TG_R6	Constraint equation violated for 14 non-consecutive DIs on 09/11/2020, 11/11/2020, 12/11/2020, 13/11/2020, 16/11/2020, 17/11/2020 and 29/11/2020, with max violation of 28.25 MW occurring on 29/11/2020 at 0750 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
F_T_AUFLS2_R6	Constraint equation violated for 7 non-consecutive DIs on 11/11/2020, 13/11/2020 and 29/11/2020 with max violation of 19.22 MW occurring on 11/11/2020 at 0735 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
N_FINLYSF_FLT_30	Constraint equation violated for 6 consecutive DIs on 26/11/2020 with a max violation of 85.44 MW occurring at 1020 hrs. Constraint equation violation occurred due to Finley solar Farm non-conforming.
N_DARLSF_FLT_80	Constraint equation violated for 4 DIs on 08/11/2020 and 25/11/2020 with max violation of 12.28MW occurring on 08/11/2020 at 0810 hrs. Constraint equation violation occurred due to Darlington Pt Solar Farm non- conforming.
Q>SSRV_M020/3	Constraint equation violated for 4 DIs on 10/11/2020 and 16/11/2020 with max violation of 9.42MW occurring on 16/11/2020 at 1310 hrs. Constraint equation violation occurred due to Susan River non-conforming.
N_BKHSF_44INV	Constraint equation violated for 4 DIs on 14/11/2020 with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit.
F_Q++MUTW_L60	Constraint equation violated for 3 DIs on 16/11/2020 from 1310 to 1320 hrs with max violation of 328.23 MW occurring at 1315 hrs. Constraint equation violated due to Queensland lower 60 second service being less than the requirement.
F_Q++MUTW_L6	Constraint equation violated for 3 consecutive DIs on 16/11/2020 from 13010 to 1320 hrs with max violation of 268.23 MW occurring at 1315 hrs. Constraint equation violated due to Queensland lower 6 second service 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_Q++MUTW_L6	NSW1-QLD1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	2240 (186.67)	-281.62 (-637.24)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
F_Q++MUTW_L6	N-Q-MNSP1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	1709 (142.42)	-40.28 (-65.0)
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	1279 (106.58)	-312.04 (-459.0)
N_X_MBTE_3B	N-Q-MNSP1 Import	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	1220 (101.67)	-8.07 (-34.3)
F_MAIN++APD_TL_L6	T-V-MNSP1 Import	Out = Nil, Lower 6 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	1085 (90.42)	-436.9 (-459.0)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1024 (85.33)	66.42 (459.01)
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	892 (74.33)	-378.39 (-459.0)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	649 (54.08)	-428.06 (-458.98)
V^^N_UTYS_1	VIC1-NSW1 Export	Out = Upper Tumut to Yass (2) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	561 (46.75)	513.35 (696.85)
V^^N_UTYS_1	V-S-MNSP1 Export	Out = Upper Tumut to Yass (2) 330kV line, avoid voltage collapse around Murray for loss of all APD potlines	551 (45.92)	-92.59 (49.04)

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.

Table 6 Non-Real-Time Constraint Automation usage

Constraint Set ID	Date Time	Description
CA_SYDS_4EBD234F	11/11/2020 00:40 to 11/11/2020 10:40	The automated constraint equation was created to manage overloading on Robertstown No.1 transformer during an outage of No.2 transformer.

2.5.1 Further Investigation

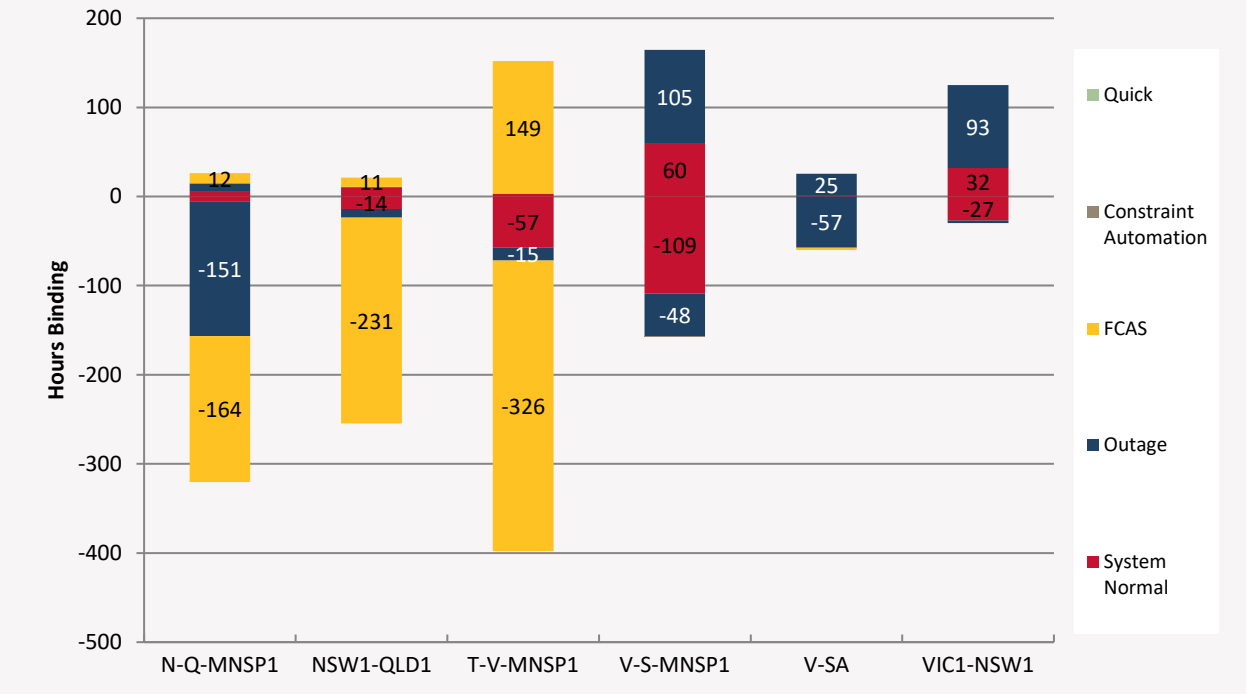
CA_SYDS_4EBD234F: Constraint equations S>>NIL_RBTX_RBTX_1 and S>>RBTX2_NIL_RBTX1 have been modified to create additional operating margin.

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.

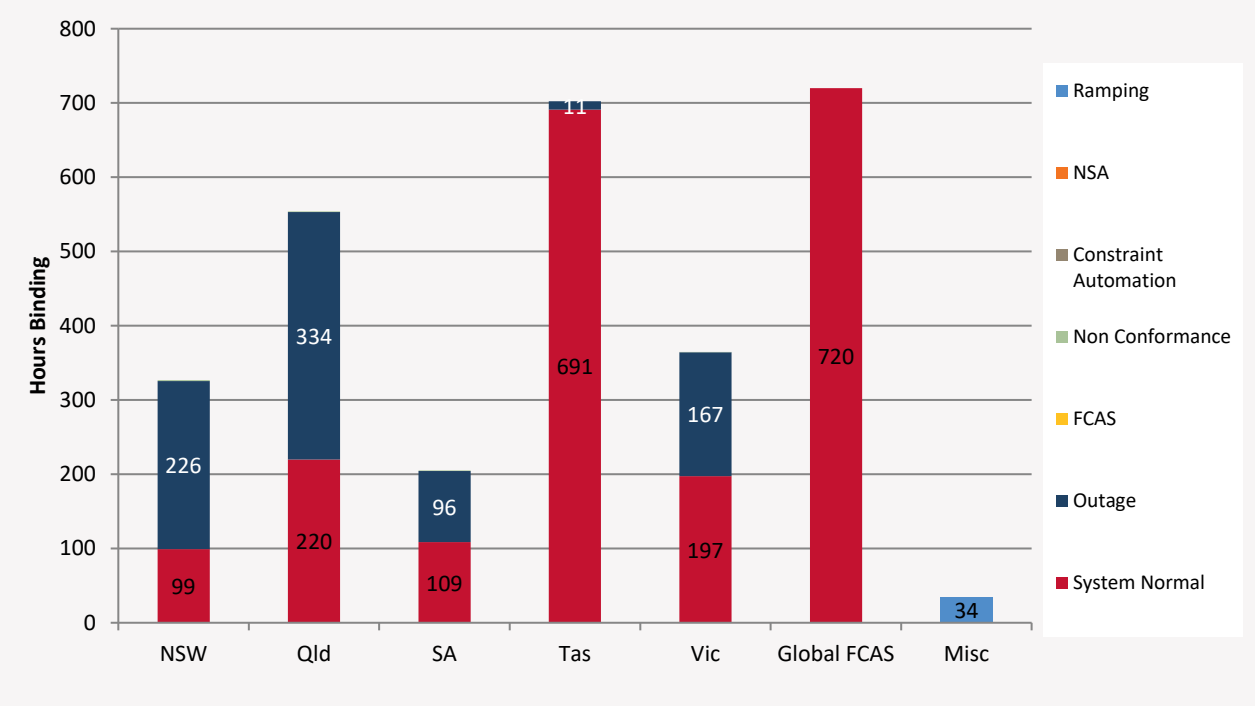
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

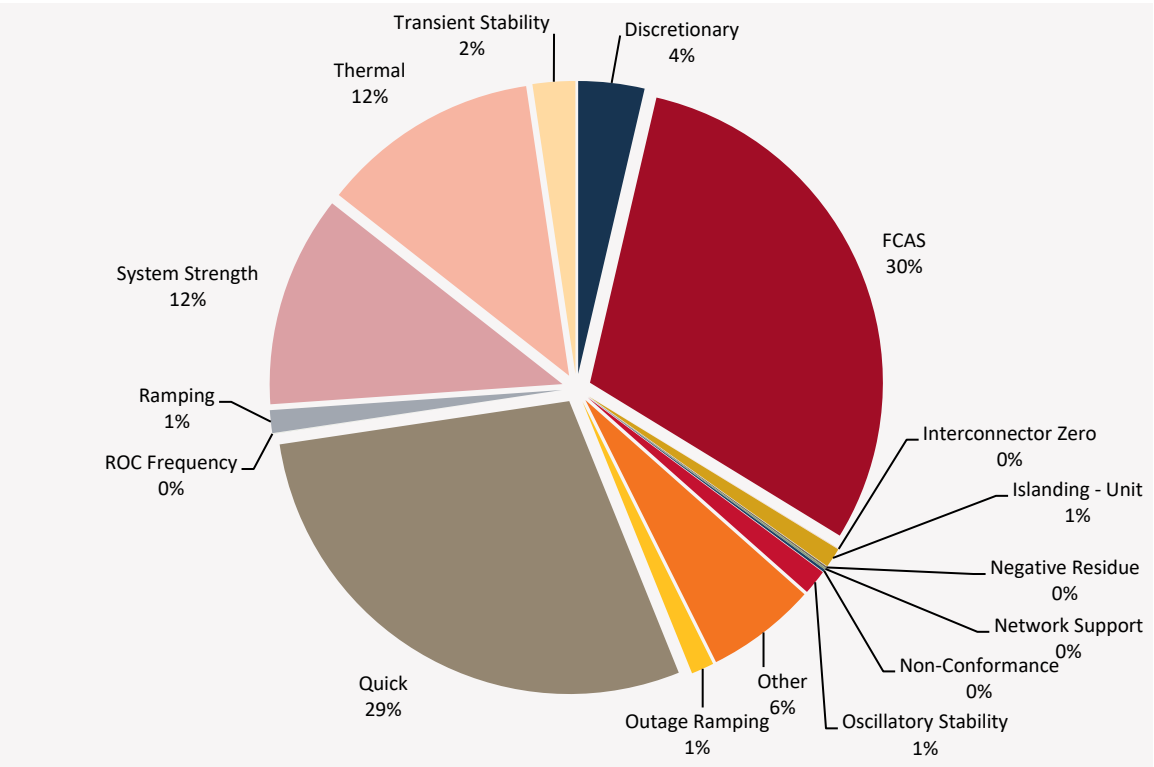
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

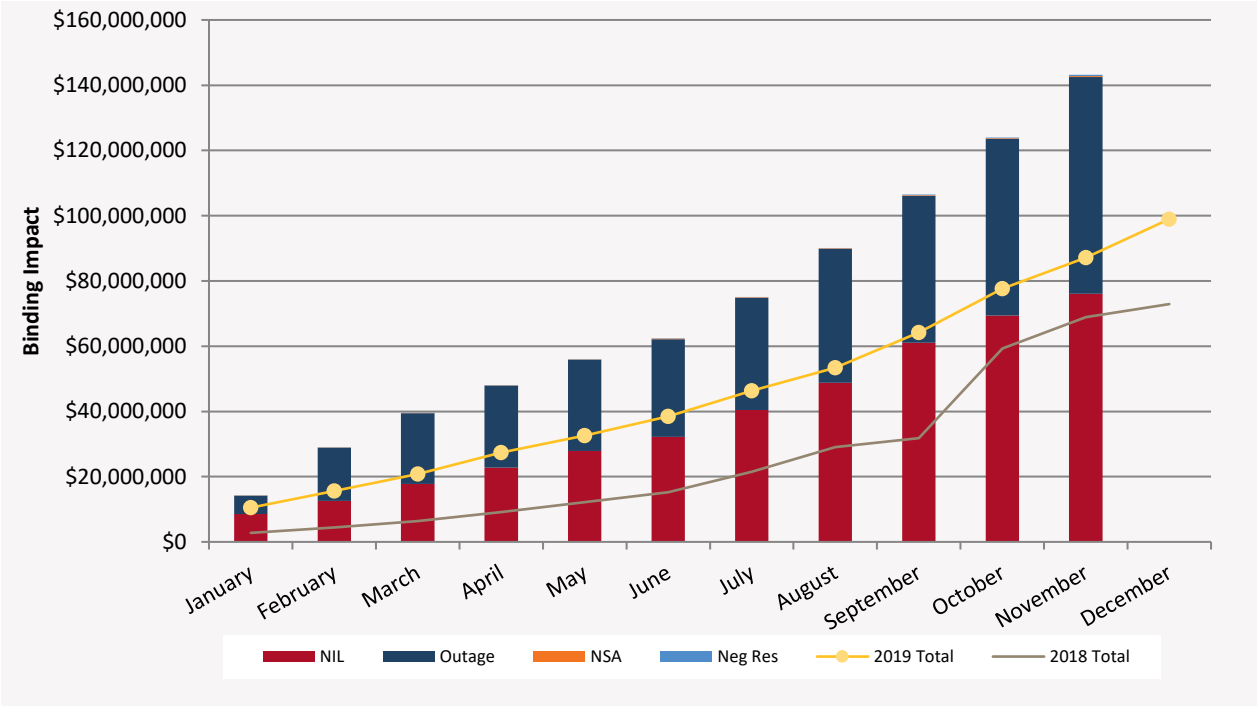
Figure 3 Binding by limit type



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_BYPASS_HW_SY_V3	Out=Three SMTS 500kV CBs for HWTS & SYTS line (#1 or #2), temporary bypass for HWTS to SYTS direct line, avoid trans. instability for fault and trip of a HWTS-SYTS or HWTS-SMTS 500kV line, VIC accelerates, Basslink VIC to TAS, Yallourn W Unit 1 on 220 kV.	25	4,171% (373.52)	311% (191.5)
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	11	1,870% (9,492)	573% (2,718)

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^SML_BEKG_4	Out = Bendigo to Kerang 220kV line, avoid voltage collapse for loss of Horsham to Ararat 220kV line	33	1,019% (115.76)	239% (60.11)
V::N_BYPASS_HW_SY_S3	Out=Three SMTS 500kV CBs for HWTS & SYTS line(#1 or #2), bypass for HWTS to SYTS direct line, avoid trans. instability for trip of a HWTS-SYTS or HWTS-SMTS 500kV line, SA accelerates, Basslink VIC->TAS. YPS #1 on 220kV. Only applied during Heywood SA->VIC	18	816% (556)	150% (267.14)
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	194	810% (28.1)	82.93% (9.28)
Q_STR_311393_10MEWF	Limit Mt Emerald to 20% if Stan>=3+CalB>=1+CalC>=1+Glad>=3+Kar>=3+(Stan+Cal+Glad)>=9,NQLD>450&470(AVG),Ross_FN>250&270(AVG),65%if Stan>=3+CalB+C>=3+Glad>=3+(Stan+Cal+Glad)>=10+Kar>=3+Bar>=1, NQLD>650&670(AVG),Ross_FN>350&370(AVG),0 otherwise.	3	225% (81.)	75.% (27.)
N>Q-MUTW_2	Out= Muswellbrook-Tamworth(88), avoid Liddell->Tamworth(84) OL on trip of largest QLD unit; Fb	9	212% (399.81)	76.99% (207.29)
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	179	204% (169.63)	9.41% (34.39)
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.	117	188% (342.77)	64.68% (180.6)
V:T_NIL_BL_1	Outage = Nil, Basslink in service, limit Basslink flow to Tasmania at low Tas fault levels to avoid inverter commutation instability	130	185% (601)	86.8% (299.45)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V^SML_BEKG_4: Investigated and no improvement can be made to the constraint equation at this stage.

Q_STR_311393_10MEWF: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_BYPASS_HW_SY_V3: Investigated and no improvement can be made to the constraint equation at this stage. It is likely to be completely reviewed or removed at later stage.

V::N_BYPASS_HW_SY_S3: Investigated and no improvement can be made to the constraint equation at this stage.

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>Q-MUTW_2: Constraint equation is currently under investigation.

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.

T::T_NIL_1: Investigated and no improvement can be made to the constraint equation at this stage.

V:T_NIL_BL_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 November 2020.

Table 8 Generator and transmission changes

Project	Date	Region	Notes
Wellington Solar Farm	4 November 2020	NSW1	New Generator
Collector Wind Farm	10 November 2020	NSW1	New Generator
Sunraysia 1 Solar Farm	10 November 2020	NSW1	New Generator
Molong Solar Farm	10 November 2020	NSW1	New Generator
Yatpool Solar Farm	17 November 2020	VIC1	New Generator
Moorabool Wind Farm	19 November 2020	VIC1	New Generator
Crudine Ridge Wind Farm	24 November 2020	NSW1	New Generator

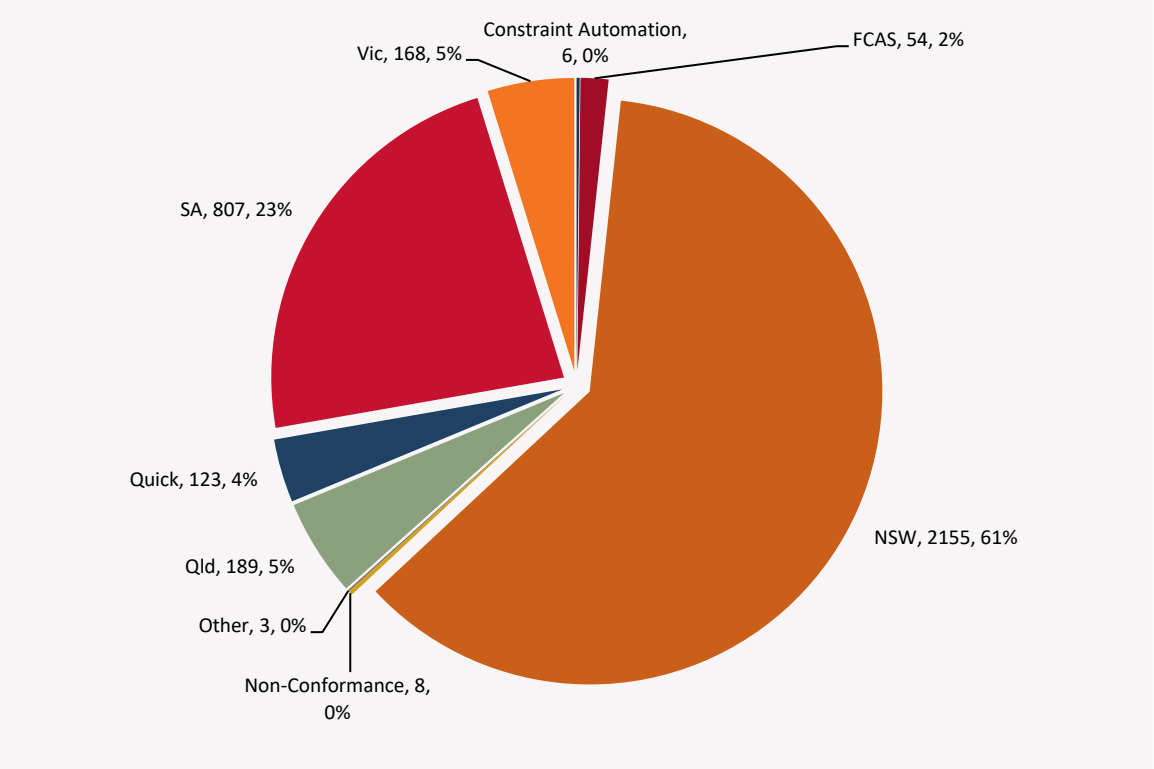
3.1 Constraint Equation Changes

The following pie chart indicates the regional location of constraint equation changes. For details on individual constraint equation changes refer to the Weekly Constraint Library Changes Report[2] or the constraint equations in the MMS Data Model.[3]

[2] AEMO. *NEM Weekly Constraint Library Changes Report*. Available at: http://www.nemweb.com.au/REPORTS/CURRENT/Weekly_Constraint_Reports/

[3] AEMO. *MMS Data Model*. Available at: https://www.aemo.com.au/energy-systems/market-it-systems/nem-guides/wholesale-it-systems-software

Figure 5 Constraint equation changes



The following graph compares the constraint equation changes for the current year versus the previous two years. The current year is categorised by region.

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