Monthly Constraint Report

June 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 June 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	2061 (171.75)	8/05/2020
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	1546 (128.83)	19/06/2020
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.	1390 (115.83)	20/05/2020
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)	1180 (98.33)	1/01/2020
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	789 (65.75)	11/03/2020
V^^N_NIL_1	Out = Nil, avoid voltage collapse around Murray for loss of all APD potlines	442 (36.83)	15/05/2019
SVML_ZERO	SA to Vic on ML upper transfer limit of 0 MW	441 (36.75)	21/08/2013
Q_STR_333104_MEWF70	Limit Mt Emerald WF to 70 % capacity if Stan>=3+Cal>=3+Glad>=3+ (Stan+Cal+Glad) >=10+Kar>=4. Zero otherwise	440 (36.66)	6/05/2020

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
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	418 (34.83)	18/06/2019
N_BKHSF_40INV	Limit Broken Hill Solar Farm upper limit to 0 MW if number of inverter available exceed 40. Constraint swamp out otherwise. DS only	404 (33.66)	5/09/2019

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_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	1,590,569	19/06/2020
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.	1,402,895	20/05/2020
Q_STR_333104_MEWF70	Limit Mt Emerald WF to 70 % capacity if Stan>=3+Cal>=3+Glad>=3+ (Stan+Cal+Glad) >=10+Kar>=4. Zero otherwise	453,912	6/05/2020
V_MURRAWRWF_MAX	Limit MW output of Murra Warra wind farm to hold point levels during day/night	386,981	29/05/2020
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)	371,233	1/01/2020
V_MURRAWRWF_FLT_90	Limit Murra Warra Wind Farm upper limit to 90 MW to manage system stability on the next contingency due to voltage oscillation	202,626	2/09/2019
S_WIMK_270	Out =Willalo-Mokota 275kV line O/S, discretionary upper limit for North Brown Hill WF + Bluff WF + Willogolechie WF <= 270 MW	171,591	29/10/2018
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	89,584	19/06/2020

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
	Gorge generators, Zero if it does not meet minimum generator online. Refer to TOA 393		
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	74,841	23/05/2019
N_STWF1_ZERO	Silverton wind farm upper limit of 0 MW	74,116	6/02/2018

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_AUFLS2_R6	TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme.	7 (0.58)	4/05/2018
F_T_NIL_MINP_R6	Out= NIL, ensure minimum quantity of TAS R6 FCAS requirement provided through proportional response, considering Basslink headroom	5 (0.41)	30/04/2018
Q>YLTX_DS	Out = Nil, limit to Maryrorough Solar Farm to ratings of Yarranlea 110/33kV transformer(s), DS formulation only	5 (0.41)	25/02/2020
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.	3 (0.25)	26/09/2019
NSA_Q_BARCALDN	Network Support Agreement for Barcaldine GT to meet local islanded demand for the planned outage of 7153 T71 Clermont to H15 Lilyvale or 7154 T72 Barcaldine to T71 Clermont 132kV line	2 (0.16)	6/05/2015
F_T+LREG_0050	Tasmania Lower Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	1 (0.08)	29/01/2015
F_T++NIL_MG_RECL_R5	Out = Nil, Raise 5 min requirement for a Tasmania Reclassified Woolnorth Generation Event, Basslink able to transfer FCAS, reduce by very fast response on Basslink, include fault-ride through on windfarms+Basslink	1 (0.08)	2/12/2016
NSA_V_BDL02_40	Bairnsdale Unit 2 >= 40 MW for Network Support Agreement	1 (0.08)	21/08/2013
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	1 (0.08)	12/04/2016
F_T+RREG_0050	Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS	1 (0.08)	29/01/2015

2.3.1 Reasons for constraint equation violations

Table 4 Reasons for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
F_T_AUFLS2_R6	Constraint equation violated for 7 non-consecutive DIs with max violation of 19.1 MW occurring on 13/06/2020 at 0235 hrs. Constraint equation violation occurred due to Tasmania raise 6-second service availability being less than the requirement.
F_T_NIL_MINP_R6	Constraint equation violated for 5 DIs with max violation of 27 MW occurring on 3/06/2020 at 0505 hrs and 0510 hrs. Constraint equation violation occurred due to the same reason as F_T_AUFLS2_R6.
Q>YLTX_DS	Constraint equation violated for 5 DIs with the max violation of 0.12 MW occurring on 10/06/2020 at 1145 hrs. Constraint equation violation occurred due to Maryrorough solar farm non-conforming.
N_FINLEYSF_49_INV	Constraint equation violated for 3 DIs on 04/06/2020 at 1335 hrs to 1340 hrs and on 24/06/2020 at 1020 hrs. Max violation of 29.03 MW occurred on 04/06/2020 at 1335 hrs. Constraint equation violation occurred due to Finley solar farm exceeding their inverter limits.
NSA_Q_BARCALDN	Constraint equation violated for 2 DIs on 12/06/2020 at 0215 hrs and 0220 hrs with max violation of 15 MW occurring at 0215 hrs. Constraint equation violation occurred due to Barcaldine GT non-conforming.
F_T+LREG_0050	Constraint equation violated for 1 DI on 25/06/2020 at 0255 hrs with violation degree of 44 MW. Constraint equation violation occurred due to Tasmania lower regulation service availability being less than the requirement.
F_T++NIL_MG_RECL_R5	Constraint equation violated for 1 DI on 02/06/2020 at 1615 hrs with violation degree of 20.66 MW. Constraint equation violation occurred due to the same reason as F_T_AUFLS2_R6.
NSA_V_BDL02_40	Constraint equation violated for 1 DI on 19/06/2020 at 1705 hrs with violation degree of 5.26 MW. Constraint equation violation occurred due to Bairnsdale unit 2 being limited by its start-up profile.
F_T+NIL_WF_TG_R6	Constraint equation violated for 1 DI on 25/06/2020 at 0505 hrs with violation degree of 2.25 MW. Constraint equation violation occurred due to the same reason as F_T_AUFLS2_R6.
F_T+RREG_0050	Constraint equation violated on 25/06/2020 at 0255 hrs with violation degree of 0.0001 MW. Constraint equation violation occurred due to Tasmania raise regulation 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)
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	2051 (170.92)	-67.61 (8.29)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1977 (164.75)	283.79 (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	1182 (98.5)	129.18 (-439.29)

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	1123 (93.58)	-368.34 (-642.27)
F_Q++MUTW_L6	N-Q-MNSP1 Import	Out = Muswellbrook to Tamworth (88) line, Qld Lower 6 sec Requirement	1091 (90.92)	-46.27 (-129.6)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	971 (80.92)	232.62 (446.01)
N^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	789 (65.75)	-243.54 (-811.68)
F_Q++LDTW_L6	NSW1-QLD1 Import	Out = Liddell to Tamworth (84) line, Qld Lower 6 sec Requirement	773 (64.42)	-474.09 (-810.0)
F_Q++LDTW_L6	N-Q-MNSP1 Import	Out = Liddell to Tamworth (84) line, Qld Lower 6 sec Requirement	765 (63.75)	-48.23 (-117.38)
N^^V_NIL_1	V-S-MNSP1 Import	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	693 (57.75)	109.69 (0.0)

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_4DE6D9E8	01/06/2020 10:40 to 01/06/2020 10:50	The automated constraint equation was created to manage overloading of the Ballarat to Waubra 220 kV line on trip of the Bendigo to Kerang 220 kV line under system normal condition. The existing constraint equation V>>V_NIL_9 was not adequate to manage the issue and it has now been updated.
CA_BRIS_4DE6DCA9	01/06/2020 10:50 to 01/06/2020 12:45	The constraint automation was an improved version of CA_BRIS_4DE6D9E8.

2.5.1 Further Investigation

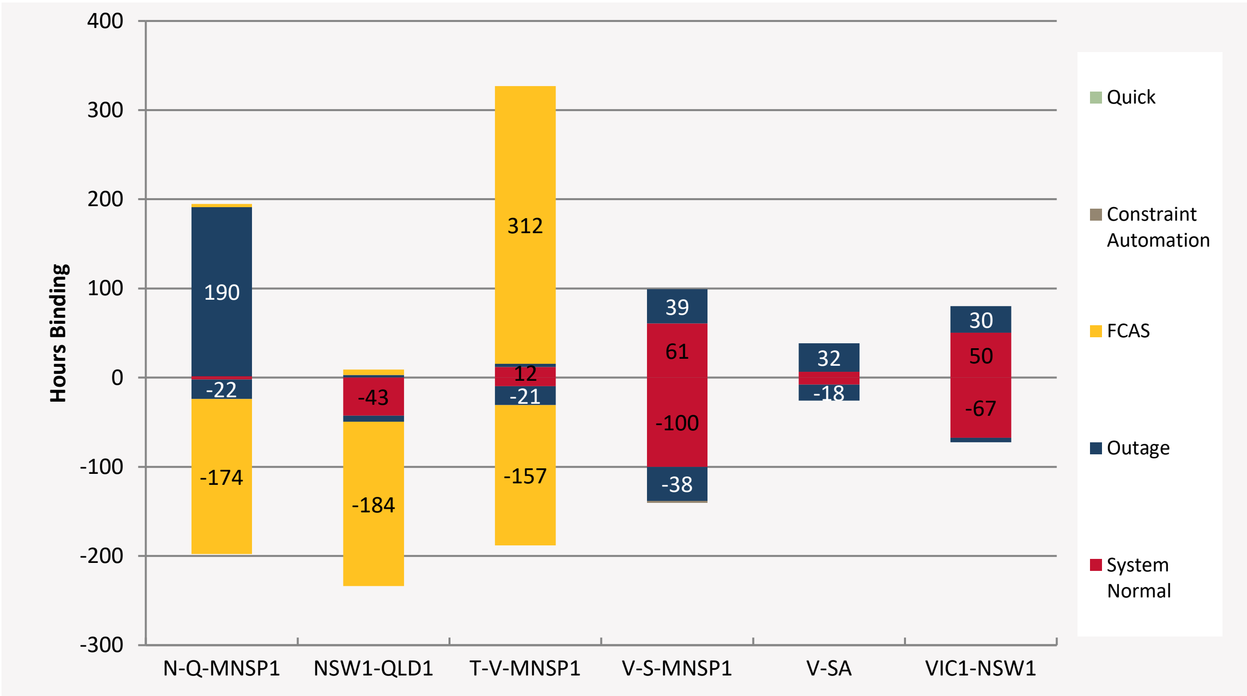
CA_BRIS_4DE6D9E8 and CA_BRIS_4DE6DCA9: The existing system normal constraint equation (V>>V_NIL_9) has since been updated to manage the overloading of Ballarat to Waubra 220 kV line on the trip of Bendigo to Kerang 220 kV line.

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.

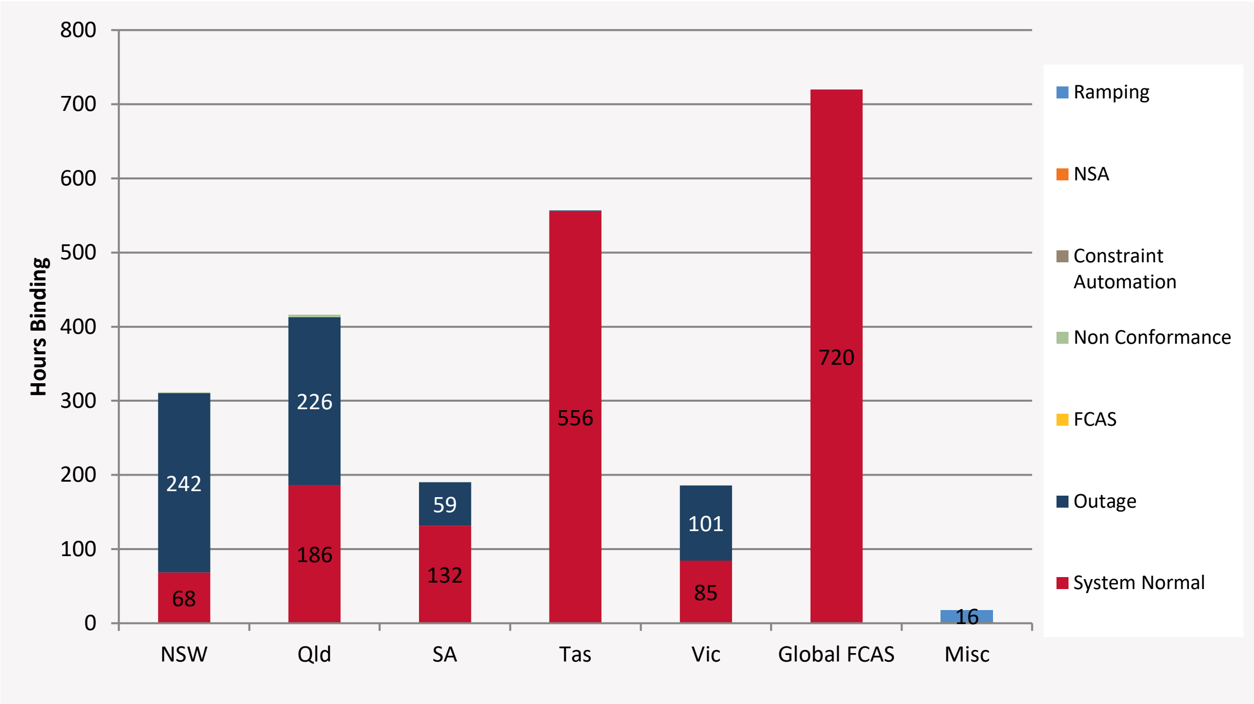
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

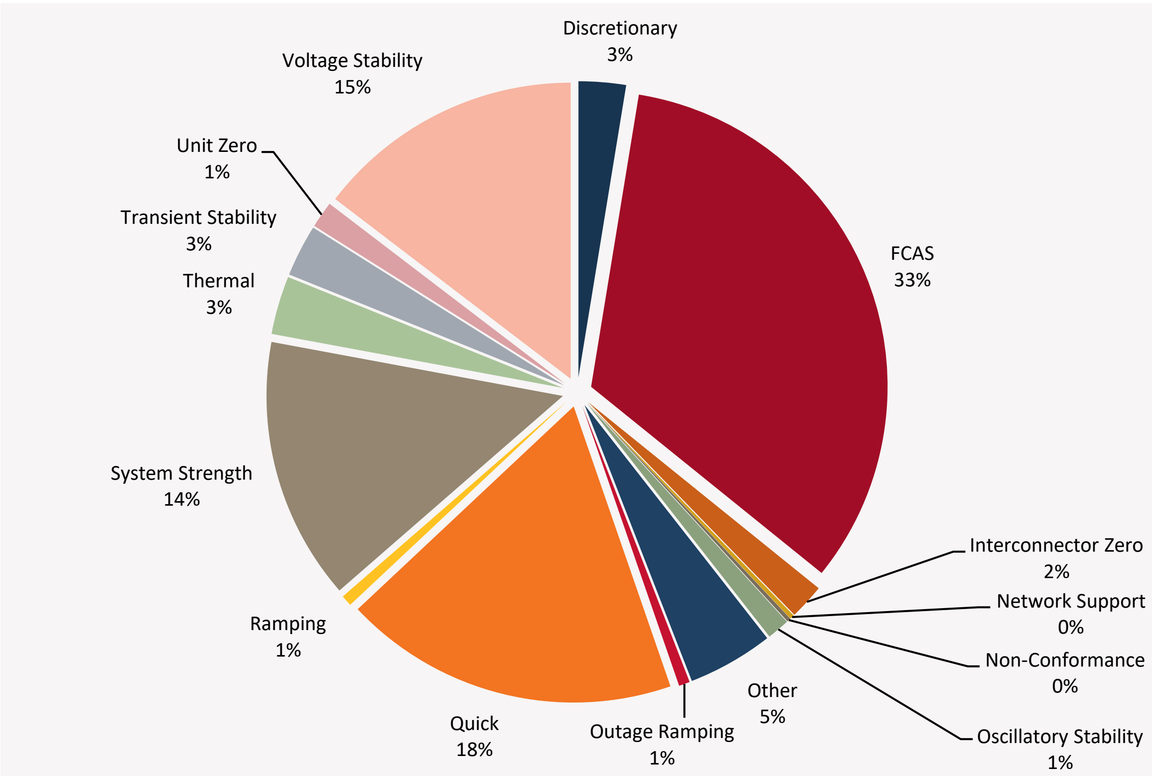
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

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

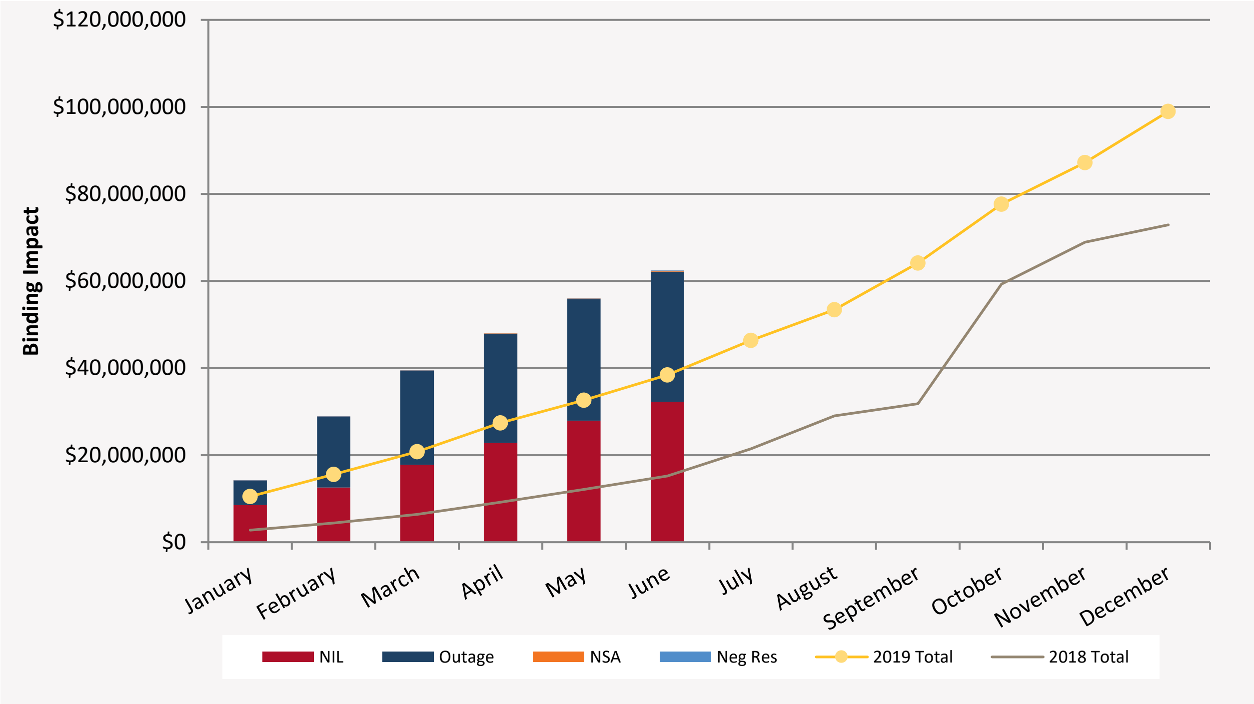
Figure 3 Binding by limit type



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
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	30	12,600,000% (144.)	1,260,044% (75.)
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	474	46,017% (132.55)	475% (36.54)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
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.	13	437% (283.22)	157% (98.8)
V^SML_BUDP_3	Out = Buronga to Balranald (X3) or Balranald to Darlington Pt (X5) 220 kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	7	394% (154.7)	130.82% (72.59)
N^N_CHLS_1	Out= Coffs Harbour to Lismore (89), avoid voltage collapse on trip of Koolkhan to Lismore (967), swamp out when all 3 Directlink O/S	62	248% (41.08)	32.2% (12.7)
N^^V_CNCW_1	Out = Canberra-Capital (6) or Kangaroo Valley to Capital (3W), avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	41	213% (175.57)	74.86% (89.67)
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.	28	172% (211.28)	40.12% (84.22)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Southern NSW for loss of the largest Vic generating unit or Basslink	276	124.26% (330.31)	37.74% (123.07)
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	8	100.% (80.)	100.% (80.)
Q_NIL_STRGTH_SMSF	Out = Nil, limit Sun Metal 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	10	100.% (86.)	100.% (86.)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_EPMB_S2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_EPMB_V2: Investigated and no improvement can be made to the constraint equation at this stage.

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

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

N^N_CHLS_1: Investigated and no improvement can be made to the constraint equation at this stage.

N^^V_CNCW_1: Investigated and no improvement can be made to the constraint equation at this stage.

N^^V_NIL_1: The Pre-dispatch formulation for this constraint equation was recalculated in February 2020 (with an update to the limit advice). Pre-dispatch formulation were improved in March 2020. No further improvements can be made at this stage

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

Q_NIL_STRGTH_SMSF: 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 June 2020.

Table 8 Generator and transmission changes

Project	Date	Region	Notes

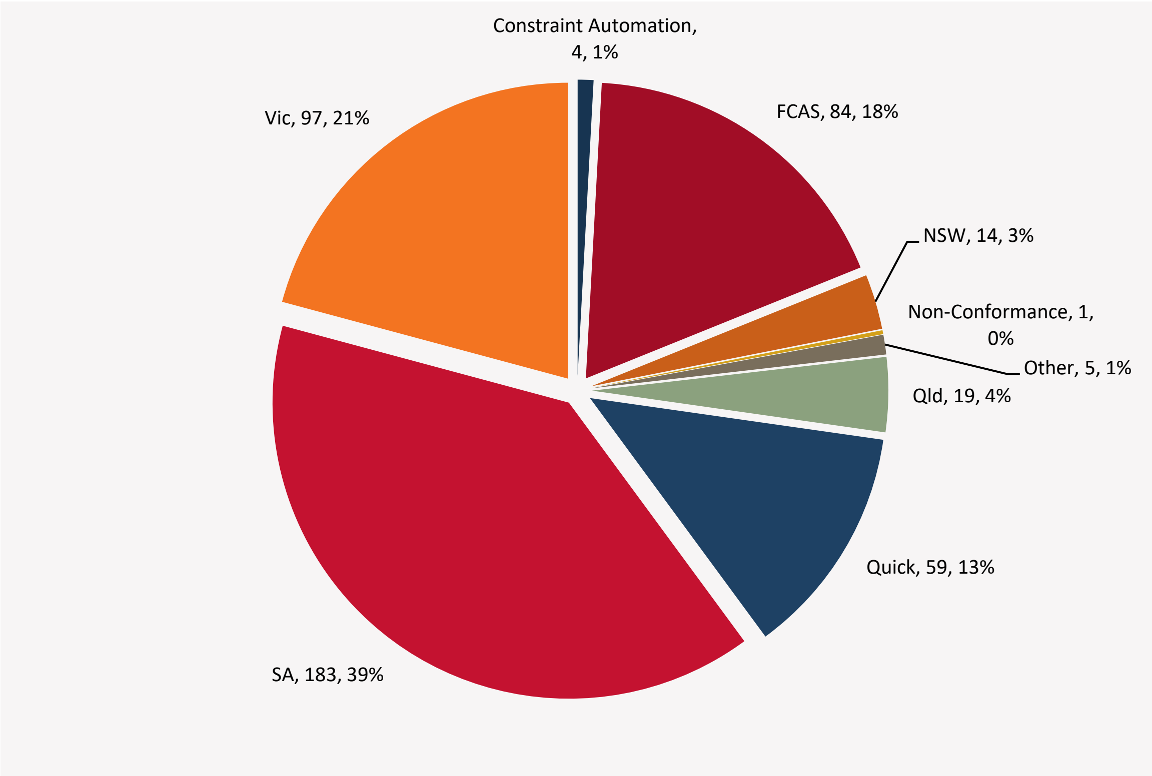
3.1 Constraint Equation Changes

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