AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Monthly Constraint Report

May 2019

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 May 2019. 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>V_NIL_SETX_SETX1	Out= Nil, avoid overloading a South East 132/275 kV transformer on trip of the remaining South East 132/275 kV transformer(for Transformer component SECS O/S), Feedback	2544 (212.0)	8/05/2019
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	2354 (196.16)	15/05/2019
T>T_LIPM_110_2A	Out= either Liapootah - Waddamana (tee) - Palmerston 220 kV line, avoid O/L Palmerston to Waddamana 110 line (flow to South) on trip of the remaining Liapootah to Waddamana (tee) to Palmerston 220 kV line, feedback	1222 (101.83)	24/04/2019
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	653 (54.41)	11/04/2019
N_X_MBTE_3B	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	602 (50.16)	25/11/2013
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 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.	594 (49.5)	5/12/2018
V_KIATAWF_FLT_0	Limit Kiata Wind Farm upper limit to 0 MW to manage system stability on the next contingency due to fault level issue	359 (29.91)	13/02/2019
Q>>WOPW_WOSP_WOGP_2	Out= Woolooga to Palmwoods (810) 275kV line, avoid O/L Woolooga to Gympie (748/2) 132kV line on trip of Woolooga to South Pine (807) 275kV line, Feedback	350 (29.16)	29/05/2019

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
V_T_NIL_FCSPS	Basslink limit from Vic to Tas for load enabled for FCSPS	337 (28.08)	20/12/2016
N_X_MBTE2_B	Out= two Directlink cables, Qld to NSW limit	313 (26.08)	25/11/2013

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
S>V_NIL_SETX_SETX1	Out= Nil, avoid overloading a South East 132/275 kV transformer on trip of the remaining South East 132/275 kV transformer(for Transformer component SECS O/S), Feedback	1,276,874	8/05/2019
S_NIL_STRENGTH_1	Upper limit (1460 to 1295 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.	593,938	5/12/2018
V_BANSF_45_22INV	Limit Bannerton Solar Farm upper limit to 45 MW with max 22 inverter available, upper limit set to 0 MW if number of inverter available exceed 22. This is to manage voltage oscillation	337,214	21/03/2019
N_COLEASF1_ZERO	Coleambally solar farm upper limit of 0 MW	296,928	19/06/2018
S-TBTX4_TBSF1_80	Out =Tailem Bend 132/275 kV #4 Transformer O/S, constrain Tailem Bend (Coorong) Solar PV to 80 MW to manage voltage collapse for trip of Tailembend-Mobilong 132kV line	255,156	15/05/2019
S>KNPW_SETX_SETX1	Out=Penola West-Kincraig 132kV line, avoid overloading a South East 132/275 kV transformer on trip of the remaining South East 132/275 kV transformer(for Transformer component SECS O/S), Feedback	221,071	14/03/2019
S_DVRB_270	Out = DV-BL 275kV line Or MK-RB 275kV line O/S, discretionary upper limit for North Brown Hill WF + Bluff WF + Willogolechie WF + Hallet Hill WF (i.e. generation + load component) <= 270 MW	192,927	13/04/2018

1 The MCC re-run relaxes any violating constraint equations and constraint equations with a marginal value equal to the constraint equation's violation penalty factor (CVP) x market price cap (MPC). The calculation caps the marginal value in each DI at the MPC value valid on that date. MPC is increased annually on 1st July.

Constraint Equation ID (System Normal Bold)	Description	∑ Marginal Values	Change Date
F_MAIN+NIL_DYN_REG	Mainland Raise Regulation Requirement, Feedback in Dispatch, increase by 60 MW for each 1s of time error below -1.5s	184,028	23/05/2019
V_MWWF_GFT_5	Out= Murra Warra WF associated fast tripping scheme (disabled), Limit Murra Warra Windfarm upper limit to 5 MW, DS only. Swamp out if the scheme is in service (enabled).	137,008	8/05/2019
V_CWWF_GFT_5	Out= Crowlands WF associated fast tripping scheme (disabled), Limit Crowlands Windfarm upper limit to 5 MW, DS only. Swamp out if the scheme is in service (enabled).	101,978	3/05/2019

2.3 Top 10 violating constraint equations

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

Table 3 Top 10 violating constraint equations

Constraint Equation ID (System Normal Bold)	Description	#DIs (Hours)	Change Date
S>V_NIL_SETX_SETX1	Out= Nil, avoid overloading a South East 132/275 kV transformer on trip of the remaining South East 132/275 kV transformer(for Transformer component SECS O/S), Feedback	28 (2.33)	8/05/2019
Q>NIL_BI_CAGS_CALV_O	Out= Nil, H8 Boyne Island feeder bushing (FB) limit on Calliope River to Boyne Island 132 kV lines, 7104/7105 (T022 Callide A to T152 Gladstone South) 132 kV lines closed with 132 kV split between T022 Callide A and H015 Lilyvale.	13 (1.08)	11/01/2019
T>T_LIPM_110_2A	Out= either Liapootah - Waddamana (tee) - Palmerston 220 kV line, avoid O/L Palmerston to Waddamana 110 line (flow to South) on trip of the remaining Liapootah to Waddamana (tee) to Palmerston 220 kV line, feedback	11 (0.91)	24/04/2019
T>T_BUSH1_220	Out = Burnie to Sheffield 220kV line, West Coast 220/110 kV parallel open, avoid O/L a Sheffield 220/110kV transformer for loss of the other Sheffield 220/110kV transformer	8 (0.66)	22/03/2017
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	5 (0.41)	2/12/2016
NSA_V_BDL02_30	Bairnsdale Unit 2 >= 30 MW for Network Support Agreement	5 (0.41)	21/08/2013
F_T+FASH1_2C_TG_R6	Out = either Farrell to Sheffield (1 or 2) line with John Butters, Tribute & Reece 1,2 supplying Sheffield, Tasmania Raise 6 sec requirement for loss of the remaining Farrell to Sheffield line, Basslink unable to transfer FCAS	4 (0.33)	12/04/2016
NSA_V_NPSD_100	Newport unit >= 100 MW for Network Support Agreement	4 (0.33)	21/12/2018
S>KNPW_SETX_SETX1	Out=Penola West-Kincraig 132kV line, avoid overloading a South East 132/275 kV transformer on trip of the remaining South East 132/275 kV transformer(for Transformer component SECS O/S), Feedback	4 (0.33)	14/03/2019
S^SETX_GEN_CAP	Out= One South East 275/132kV transformer O/S, avoid local voltage collapse on trip of remaining South East transformer,	4 (0.33)	28/05/2019

2.3.1 Reasons for constraint equation violations

Table 4 Reason for constraint equation violations

Constraint Equation ID (System Normal Bold)	Description
S>V_NIL_SETX_SETX1	Constraint equation violated for 28 non-consecutive DIs. Max violation of 47.25 MW occurred on 29/05/2019 at 1305hrs. Constraint equation violated due to Lake Bonney units 2 and 3 being limited by their ramp-down rates.
Q>NIL_BI_CAGS_CALV_O	Constraint equation violated for 13 non-consecutive DIs. Max violation of 15.35 MW occurred on 08/05/2019 at 1655hrs. Constraint equation violated due to Gladstone units 3 and 4 being limited by their ramp-down rates.
T>T_LIPM_110_2A	Constraint equation violated for 11 non-consecutive DIs. Max violation of 19.56 MW occurred on 13/05/2019 at 0730hrs. Constraint equation violated due to Gordon hydro units and Tungatinah hydro units being trapped in their Frequency Control Ancillary Services (FCAS) trapeziums.
T>T_BUSH1_220	Constraint equation violated for 8 consecutive DIs. Max violation of 13.16 MW occurred on 07/05/2019 at 0745hrs. Constraint equation violated due to Devils Gate hydro unit being unavailable.
F_T+NIL_MG_RECL_R6	Constraint equation violated for 5 DIs. Max violation of 59.64 MW occurred on 25/05/2019 at 1145hrs. Constraint equation violated due to Tasmania raise 6 seconds service availability being less than the requirement.
NSA_V_BDL02_30	Constraint equation violated for 5 DIs on 01/05/2019 from 0805hrs to 0825hrs with a violation degree of 30 MW for each DI. Constraint equation violated due to Bairnsdale unit 2 being limited by its start-up profile.
F_T+FASH1_2C_TG_R6	Constraint equation violated for 4 DIs. Max violation of 205.25 MW occurred on 24/05/2019 at 1205hrs. Constraint equation violated due to the same reason as F_T+NIL_MG_RECL_R6.
NSA_V_NPSD_100	Constraint equation violated for 4 DIs. Max violation of 85 MW occurred on 26/05/2019 at 0135hrs. Constraint equation violated due to Newport unit being limited by its ramp-up rate.
S>KNPW_SETX_SETX1	Constraint equation violated for 4 DIs. Max violation of 34.21 MW occurred on 07/05/2019 at 1335hrs. Constraint equation violated due to the same reason as S>V_NIL_SETX_SETX1.
S^SETX_GEN_CAP	Constraint equation violated for 4 DIs. Max violation of 26.21 MW occurred on 30/05/2019 at 1100hrs. Constraint equation violated due to the same reason as S>V_NIL_SETX_SETX1.

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^^V_NIL_1	VIC1-NSW1 Import	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	2352 (196.0)	-294.85 (-1032.1)
F_MAIN++NIL_MG_R6	T-V-MNSP1 Export	Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	1244 (103.67)	6.88 (478.0)

Constraint Equation ID (System Normal Bold)	Interconnector	Description	#DIs (Hours)	Average Limit (Max)
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	1021 (85.08)	74.79 (-474.94)
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	769 (64.08)	-69.83 (-465.69)
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	653 (54.42)	-877.44 (-1031.76)
N_X_MBTE_3B	N-Q-MNSP1 Import	Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load	602 (50.17)	-16.36 (-49.4)
F_MAIN++NIL_MG_R60	T-V-MNSP1 Export	Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS	462 (38.5)	26.16 (464.56)
Q>>WOPW_WOSP_WOGP_2	NSW1-QLD1 Export	Out= Woolooga to Palmwoods (810) 275kV line, avoid O/L Woolooga to Gympie (748/2) 132kV line on trip of Woolooga to South Pine (807) 275kV line, Feedback	349 (29.08)	-554.63 (-13.19)
N_X_MBTE2_B	N-Q-MNSP1 Import	Out= two Directlink cables, Qld to NSW limit	313 (26.08)	-69.98 (-94.2)
V_T_NIL_FCSPS	T-V-MNSP1 Import	Basslink limit from Vic to Tas for load enabled for FCSPS	298 (24.83)	-351.58 (-477.83)

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.

2.5.1 Further Investigation

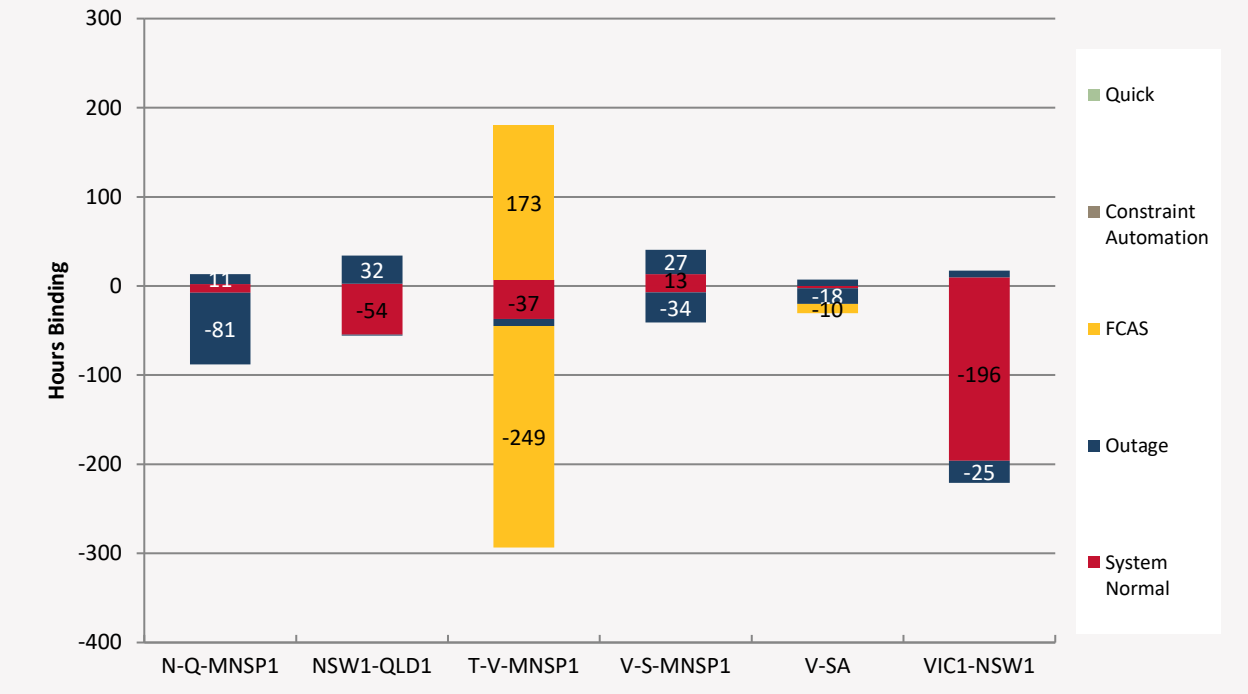
Non-real-time constraint automation was not used.

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.

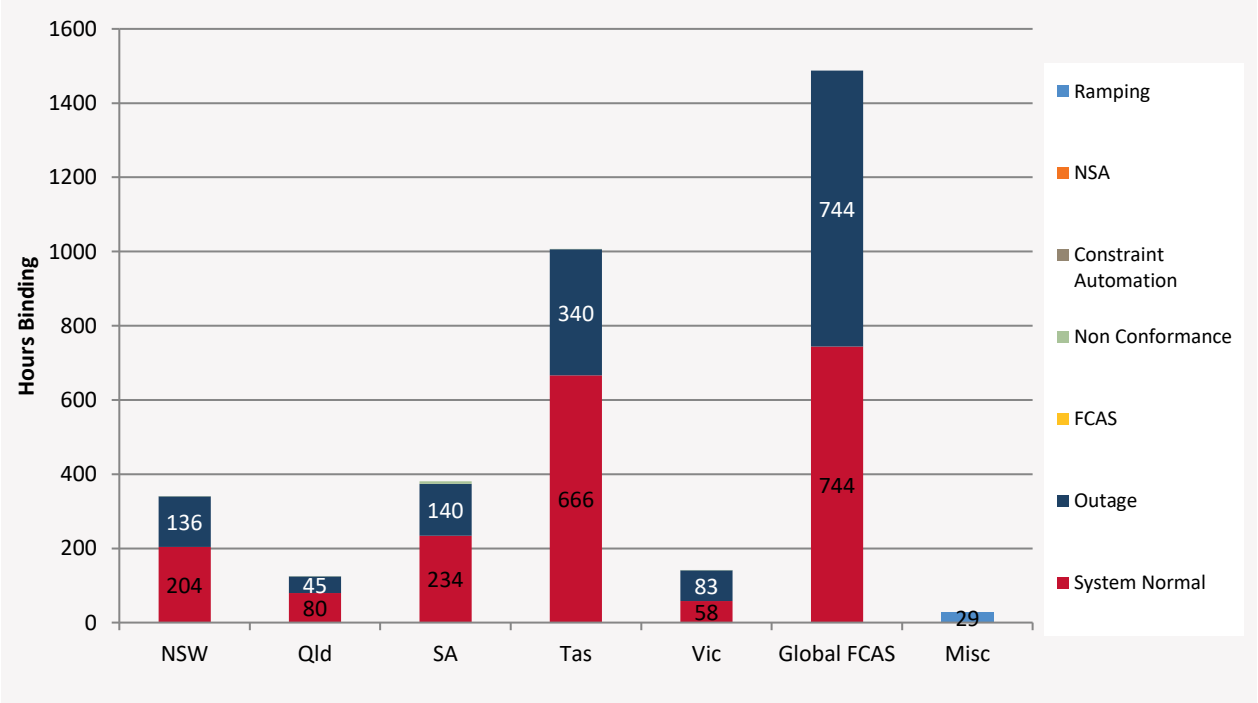
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

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.

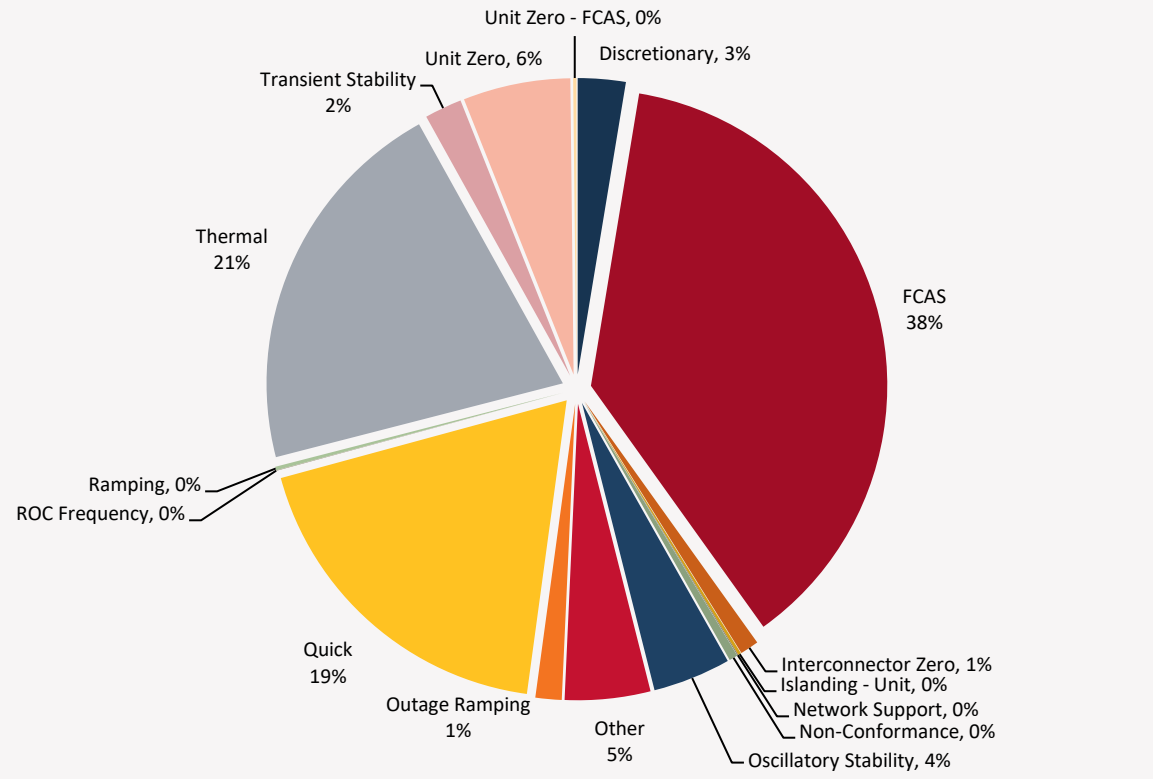
Figure 2 Regional binding dispatch hours



2.7 Binding Constraint Equations by Limit Type

The following pie charts show the percentage of dispatch intervals from for May 2019 that the different types of constraint equations bound.

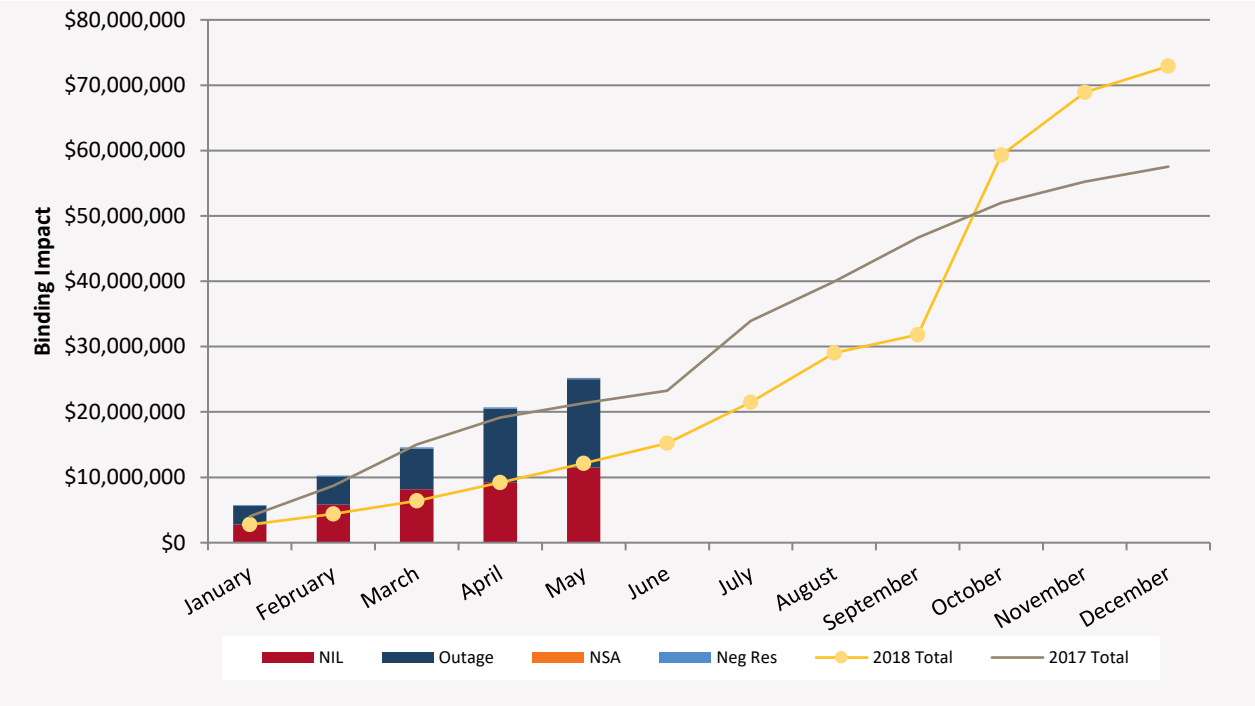
Figure 3 Binding by limit type



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
Q_NESTM_STRGTH_MEWF	Out = 822, Limit MT Emerald WF to 75% of max capacity (#40 turbine) if Kareeya > = 2 and Stanwell >= 3 and Callide >= 3 and Gladstone> = 3 and total of Stanwell, Callide and Gladstone >=10. Limit to zero otherwise. Swamp if Sun Metal+Haughton =0.	10	134,999,900% (134.99)	134,999,900% (134.99)
Q_NESTM_STRGTH_SMSF	Out = 822, Limit Sun Metal SF to 50% of max capacity (#38 inverters) if Kareeya > = 2 and Stanwell > = 3 and Callide > = 3 and Gladstone > = 3 and total of Stanwell, Callide and Gladstone > =10. Limit to zero otherwise.	10	61,000,000% (61.)	61,000,000% (61.)
Q_NESTM_STRGTH_HAUSF	Out = 822, Limit Haughton SF to 50% of max capacity (#40 inverters) if Kareeya > = 2 and Stanwell > = 3 and Callide > = 3 and Gladstone > = 3 and total of Stanwell, Callide and Gladstone > =10. Limit to zero otherwise.	9	55,000,000% (55.)	55,000,000% (55.)
N_WR_55_30WT-INV	Limit White Rock wind/solar farm upper limit to 55 MW with max 30 wind turbine and inverter available, upper limit set to 0 MW if number of wind turbine + inverter available exceed 30. This is to manage low SCR.	22	5,500,000% (55.)	5,000,009% (55.)

Constraint Equation ID (System Normal Bold)	Description	#DIs	% + Max Diff	% + Avg Diff
V_KARSF_45_21INV	Limit Karadoc Solar Farm upper limit to 45 MW with max 21 inverter available, upper limit set to 0 MW if number of inverter available exceed 21. This is to manage voltage oscillation	7	4,500,000 % (45.)	642,943 % (45.)
N_BKHSF_30_44INV	Limit Broken Hill Solar Farm upper limit to 30 MW with max 44 inverter available, upper limit set to 0 MW if number of inverter available exceed 44. This is to manage voltage oscillation	45	3,000,000 % (30.)	3,000,000% (30.)
V_GANNSF_30_12INV	Limit Gannawarra Solar Farm upper limit to 30 MW with max 12 inverter available, upper limit set to 0 MW if number of inverter available exceed 12. This is to manage voltage oscillation	5	3,000,000 % (30.)	2,400,020% (30.)
V^SML_HORC_3	Out = Horsham to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line	16	746,439% (66.2)	47,779% (35.1)
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.	19	497% (216.61)	144.07% (85.78)
N^^V_NIL_1	Out = Nil, avoid voltage collapse at Darlington Point for loss of the largest Vic generating unit or Basslink	466	372% (560)	48.16% (163.88)

2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

Q_NESTM_STRGTH_MEWF, Q_NESTM_STRGTH_SMSF: Constraint equations have been updated and are being monitored.

V_KARSF_45_21INV, V_GANNSF_30_12INV, N_BKHSF_30_44INV, N_WR_55_30WT-INV: Constraint equations have been archived and replaced with new constraint equations to improve PD performance.

N^^V_NIL_1: The Pre-dispatch formulation for this constraint equation was recalculated in early November 2017 (with an update to the limit advice). No further improvements can be made at this stage.

V::N_HWSM_V2: Investigated and no improvement can be made to the constraint equations 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 May 2019.

Table 7 Generator and transmission changes

Project	Date	Region	Notes
Haughton Solar Farm	28 May 2019	QLD	New Generator
Rugby Run Solar Farm	28 May 2019	QLD	New Generator
Numurkah Solar Farm	7 May 2019	VIC	New Generator

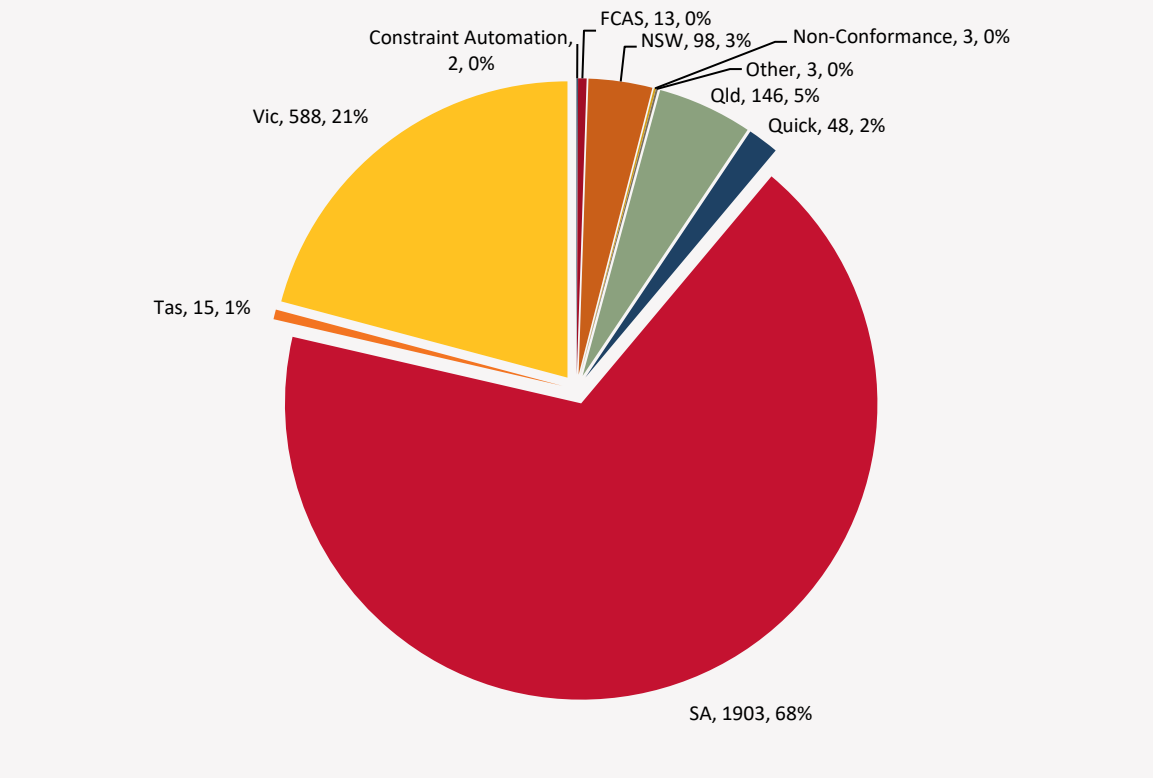
3.1 Constraint Equation Changes

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

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

[3] AEMO. *MMS Data Model*. Available at: http://www.aemo.com.au/Electricity/IT-Systems/NEM

Figure 5 Constraint equation changes



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

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