AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

# Monthly Constraint Report

## November 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 November 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 |
|---|---|---|---|
| **N>N-NIL_CLDP_1** | Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback | 2176 (181.33) | 3/12/2019 |
| SVML_ZERO | SA to Vic on ML upper transfer limit of 0 MW | 1559 (129.91) | 21/08/2013 |
| QNTE_SUPPORT | Qld to NSW on Terranora Interconnector minimum transfer >= Terranora load plus 29 MW threshold. | 963 (80.25) | 20/11/2019 |
| NQTE_-060 | NSW to Qld on Terranora Interconnector upper transfer limit of -60 MW | 959 (79.91) | 28/03/2018 |
| **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. | 949 (79.08) | 16/09/2019 |
| **V_GANWRSF_FLT_25** | Limit Gannawarra solar farm upper limit to 25 MW to manage post contingent voltage oscillation | 926 (77.16) | 4/09/2019 |
| **T>T_NIL_110_1** | Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback | 648 (54.0) | 11/01/2019 |
| **V_KARADSF_FLT_45** | Limit Karadoc solar Farm upper limit to 45 MW to manage post contingent voltage oscillation | 565 (47.08) | 19/07/2019 |
| Q_LILYSF1_ZERO | Lilyvale Solar Farm upper limit of 0 MW | 504 (42.0) | 20/08/2018 |

| Constraint Equation ID (System Normal Bold) | Description | #DIs (Hours) | Change Date |
|---|---|---|---|
| S>VMLMHNW1 | Out = Monash to North West Bend # 1 132kV line, limit Murraylink (SA to Vic) to avoid overloading Monash-North West Bend # 2 132kV line | 487 (40.58) | 17/05/2019 |

## 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 |
|---|---|---|---|
| **N>N-NIL_CLDP_1** | Out= Nil, avoid O/L Coleambally to Darlington Point 132kV line (99T) on Nil trip, Feedback | 2,227,678 | 3/12/2019 |
| **S_NIL_STRENGTH_1** | Upper limit (1300 to 1750 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements. Automatically swamps out when required HIGH combination is online. | 1,172,747 | 16/09/2019 |
| **T>T_NIL_110_1** | Out = NIL, avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line, feedback | 687,024 | 11/01/2019 |
| Q_LILYSF1_ZERO | Lilyvale Solar Farm upper limit of 0 MW | 531,081 | 20/08/2018 |
| F_S++HYSE_L60 | Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 60 sec Requirement for risk of islanding | 368,585 | 13/09/2019 |
| 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. | 299,276 | 16/09/2019 |
| F_S+TL_L6_OD | Lower 6 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load | 296,422 | 21/11/2013 |
| F_S++HYSE_L6_1 | Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 6 sec Requirement for risk of islanding, segment1 | 281,745 | 25/11/2015 |
| **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 | 271,878 | 23/05/2019 |

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 |
|---|---|---|---|
| **F_I+LREG_0210** | NEM Lower Regulation Requirement greater than 210 MW | 159,182 | 16/05/2019 |

## 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**

Table 1 – Top 10 violating constraint equations

| Constraint Equation ID (System Normal Bold) | Description | #DIs (Hours) | Change Date |
|---|---|---|---|
| F_S+PPT_R6_1 | Raise 6 sec Service Requirement for SA Generation Event, where Pelican Point GT11 or GT12 or ST is the largest generation risk in SA, Segment 1 | 35 (2.91) | 11/11/2015 |
| F_S++HYSE_L60 | Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 60 sec Requirement for risk of islanding | 24 (2.0) | 13/09/2019 |
| F_S+TL_L6_OD | Lower 6 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load | 21 (1.75) | 21/11/2013 |
| F_S+TL_L60_OD | Lower 60 sec Service Requirement for SA Network Event, Loss of Davenport to Olympic Dam West 275kV line offload the entire Olympic Dam load | 21 (1.75) | 21/11/2013 |
| SA_ISLE_STRENGTH_LB | Maximum limit (0 MW) for Lake Bonney and Canunda Wind Farm for system strength requirements when SA is at risk of separation or when islanded. | 20 (1.66) | 13/09/2019 |
| F_S++HYSE_L6_1 | Out = (Heywood to South East) or (Heywood transformers) or (Heywood to Mortlake) or (Heywood to Tarrone) or (Moorabool to Mortlake) or (Moorabool to Sydenham) or (Moorabool to Tarrone), SA Lower 6 sec Requirement for risk of islanding, segment1 | 16 (1.33) | 25/11/2015 |
| **S^NIL_PL_MAX** | Out = Nil, Maximum generation at Port Lincoln Due to voltage stability limit. | 10 (0.83) | 14/06/2019 |
| **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 | 8 (0.66) | 12/04/2016 |
| F_S+PPT_R6_2 | Raise 6 sec Service Requirement for SA Generation Event, where Pelican Point GT11 or GT12 or ST is the largest generation risk in SA, Segment 2 | 6 (0.5) | 11/11/2015 |
| **F_T_AUFLS2_R6** | TAS AUFLS2 control scheme. Limit R6 enablement based on loaded armed for shedding by scheme. | 6 (0.5) | 4/05/2018 |

### 2.3.1 Reasons for constraint equation violations

**Table 4 Reasons for constraint equation violations**

Table 2 – Reasons for Top 10 violating constraint equations

| Constraint Equation ID (System Normal Bold) | Description |
|---|---|
| F_S+PPT_R6_1 | Constraint equation violated for 35 non-consecutive DIs,11 of which were consecutive. Max violation of 49.34 MW occurred on 16/11/2019 at 1900 hrs. Constraint equation violated due to South Australia Raise 6 second service availability being less than the requirement. |
| F_S++HYSE_L60 | Constraint equation violated for 24 non-consecutive DIs. Max violation of 90.44 MW occurred on 07/11/2019 at 0535 hrs. Constraint equation violated due to South Australia Lower 60 second service availability being less than the requirement. |
| F_S+TL_L6_OD | Constraint equation violated for 21 consecutive DIs. Max violation of 218.2 MW occurred on 16/11/2019 at 1820 hrs. Constraint equation violated due to South Australia Lower 6 second service availability being less than the requirement. |
| F_S+TL_L60_OD | Constraint equation violated for 21 consecutive DIs. Max violation of 32.11 MW occurred on 16/11/2019 at 1820 hrs. Constraint equation violated due to the same reason as F_S++HYSE_L60. |
| SA_ISLE_STRENGTH_LB | Constraint equation violated for 20 consecutive DIs. Max violation of 53.49 MW occurred on 16/11/2019 at 1925 hrs. Constraint equation violated due to non-scheduled Windfarms (Lake Bonney 1 and Canunda) generating more than the requirement. |
| F_S++HYSE_L6_1 | Constraint equation violated for 16 non-consecutive DIs. Max violation of 71.29 MW occurred on 07/11/2019 at 0535 hrs. Constraint equation violated due to the same reason as F_S+TL_L6_OD. |
| **S^NIL_PL_MAX** | Constraint equation violated for 10 consecutive DIs. Max violation of 5.32 MW occurred on 11/11/2019 at 1640 hrs. Constraint equation violated due to non-scheduled Windfarm (Cathedral rock) generating more than the requirement. |
| **F_T+NIL_WF_TG_R6** | Constraint equation violated for 8 non-consecutive DIs. Max violation of 36 MW occurred on 07/11/2019 at 0750 hrs. Constraint equation violated due to the same reason as F_S+PPT_R6_1. |
| F_S+PPT_R6_2 | Constraint equation violated for 6 non-consecutive DIs. Max violation of 87.72 MW occurred on 16/11/2019 at 1900 hrs. Constraint equation violated due to the same reason as F_S+PPT_R6_1. |
| **F_T_AUFLS2_R6** | Constraint equation violated for 6 non-consecutive DIs. Max violation of 18.59 MW occurred 27/11/2019 at 0925hrs. Constraint equation violated due to the same reason as F_S+PPT_R6_1. |

## 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) |
|---|---|---|---|---|
| SVML_ZERO | V-S-MNSP1 Import | SA to Vic on ML upper transfer limit of 0 MW | 1559 (129.92) | 0.0 (0.0) |
| **F_MAIN++NIL_MG_R5** | T-V-MNSP1 Export | Out = Nil, Raise 5 min requirement for a Mainland Generation Event, Basslink able transfer FCAS | 1352 (112.67) | -8.76 (473.0) |

| 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 | 1317 (109.75) | -35.55 (473.0) |
| F_Q++BCDM_L6 | NSW1-QLD1 Import | Out = Bulli Creek to Dumaresq (8L or 8M) or Dumaresq to Sapphire (8J) line, Qld Lower 6 sec Requirement | 1178 (98.17) | -233.17 (-334.68) |
| QNTE_SUPPORT | N-Q-MNSP1 Export | Qld to NSW on Terranora Interconnector minimum transfer >= Terranora load plus 29 MW threshold. | 959 (79.92) | -46.01 (-33.2) |
| NQTE_-060 | N-Q-MNSP1 Export | NSW to Qld on Terranora Interconnector upper transfer limit of -60 MW | 958 (79.83) | -60.0 (-60.0) |
| **F_MAIN++NIL_MG_R60** | T-V-MNSP1 Export | Out = Nil, Raise 60 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS | 899 (74.92) | 56.3 (445.0) |
| **F_MAIN++APD_TL_L5** | T-V-MNSP1 Import | Out = Nil, Lower 5 min Service Requirement for a Mainland Network Event-loss of APD potlines due to undervoltage following a fault on MOPS-HYTS-APD 500 kV line, Basslink able to transfer FCAS | 838 (69.83) | 37.02 (-460.0) |
| S>VMLMHNW1 | V-S-MNSP1 Import | Out = Monash to North West Bend # 1 132kV line, limit Murraylink (SA to Vic) to avoid overloading Monash-North West Bend # 2 132kV line | 487 (40.58) | -61.7 (-92.86) |
| **S>NIL_NIL_NWMH2** | V-S-MNSP1 Import | Out= Nil, avoid O/L North West Bend-Monash #2 132kV on Nil trip, Feedback | 423 (35.25) | -58.78 (-85.31) |

## 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

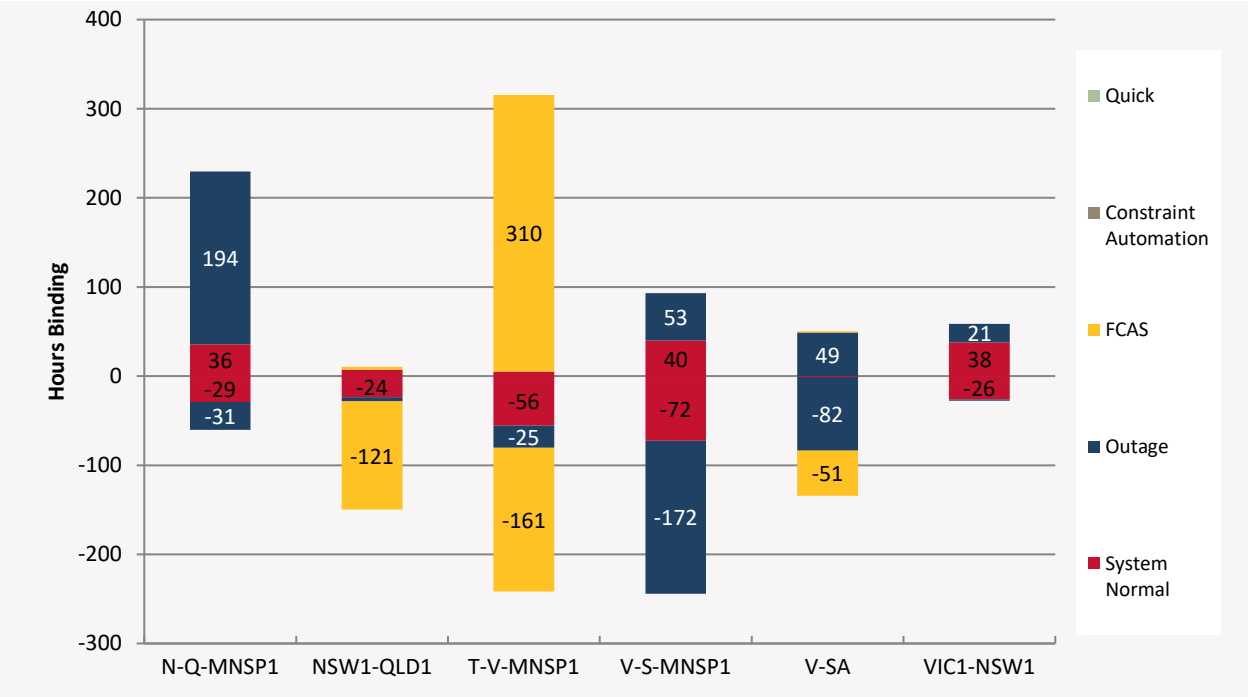
Non-real time constraint automation was not used.

## 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.

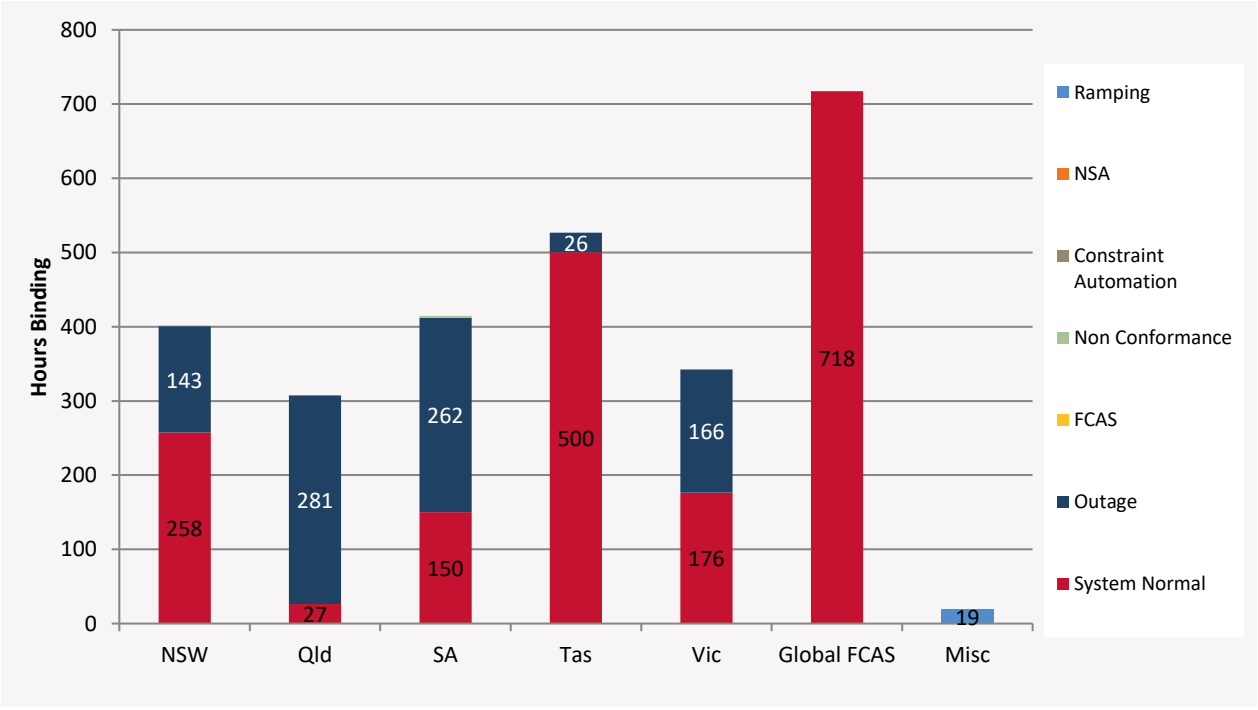
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

**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.

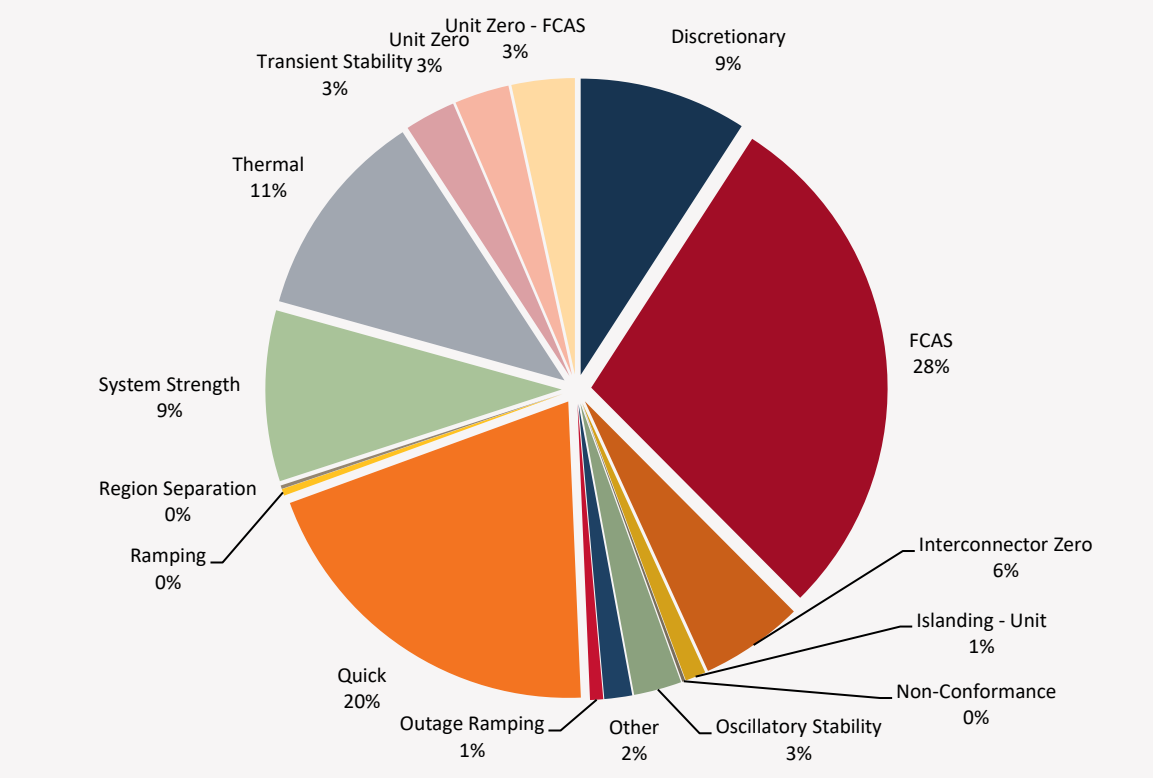
**Figure 2 Regional binding dispatch hours**



## 2.7 Binding Constraint Equations by Limit Type

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

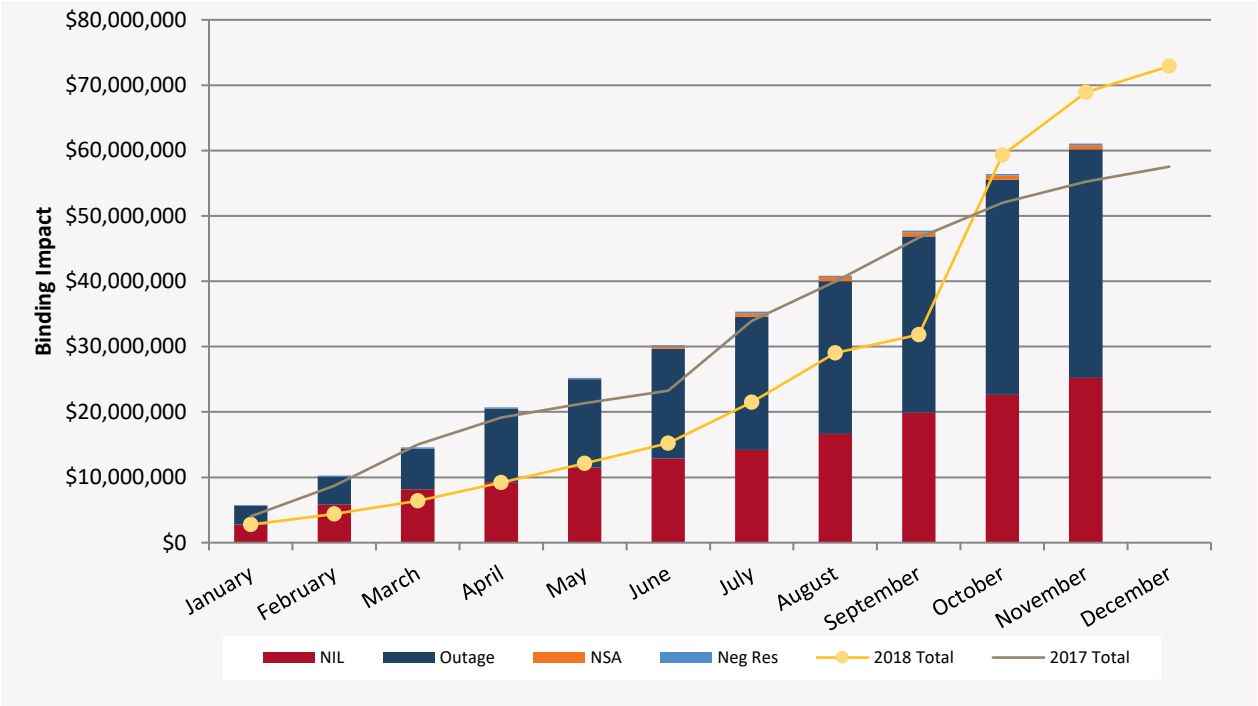
**Figure 3 Binding by limit type**




## 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_NIL_STRGTH_MEWF** | Out= Nil, Limit Mt Emerald WF to 100% capacity (53 turbines) if Kar >=2 (not behind a single Tx during daytime) + Stan >= 2 + Cal >=1 + Glad >= 3 and (Stan+Cal+Glad) >=7,75% if Kar<2,66% if no Barron Gorge. Zero otherwise. | 41 | 117,999,900 % (117.99) | 117,999,900 % (117.99) |
| Q_STR_43239_MEWF_26D | Limit Mt Emerald WF to 50% capacity (26 turbines) if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=3 + (Stan+Cal+Glad >=9) + Haughton >0 + Sun Metals >0. Zero otherwise. | 35 | 90,000,000% (90.) | 90,000,000% (90.) |
| **Q_NIL_STRGTH_HAUSF** | Out = Nil, Limit Haughton SF to 70% capacity (56 inverters) if Kar >= 2(2 TX)+ Stan>= 2 + Cal>=1 + Glad>= 3 and (Stan+Cal+Glad) >=7, Swamp if Kar >= 2 (2 TX)+ Stan >= 3 + Cal>= 3 + Gladstone >= 3 and (Stan+Cal+Glad) >=10. 50% if Kareeya< 2. Zero otherwise | 32 | 77,000,000% (77.) | 77,000,000% (77.) |
| Q_STR_43239_SMSF_38 | Limit Sun Metals SF to 50% capacity (38 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=3 + (Stan+Cal+Glad >=9). Zero otherwise. | 34 | 61,000,000% (61.) | 61,000,000% (61.) |

| Constraint Equation ID (System Normal Bold) | Description | #DIs | % + Max Diff | % + Avg Diff |
|---|---|---|---|---|
| Q_STR_43239_HASF_40 | Limit Haughton SF to 50% capacity (40 inverters), if (Kareeya >= 2 + Invicta on OR Kareeya=4) + Stanwell >=3 + Callide >=2 + Gladstone >=3 + (Stan+Cal+Glad >=9). Zero otherwise. | 37 | 55,000,000% (55.) | 55,000,000% (55.) |
| 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. | 50 | 6,468% (119.74) | 298% (40.17) |
| V^SML_HORC_3 | Out = Horsham to Murra Warra to Red Cliffs 220kV line OR Murra Warra to Red Cliffs 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line | 5 | 5,408% (147.97) | 1,289% (97.55) |
| V^SML_BAWB_3 | Out = Ballarat to Waubra 220kV line, avoid voltage collapse for loss of Bendigo to Kerang 220kV line | 12 | 2,789% (40.12) | 266% (18.29) |
| **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 | 27 | 1,651% (48.19) | 173% (29.9) |
| 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. | 14 | 561% (111.83) | 278% (74.52) |

### 2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

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

Q_STR_43239_MEWF_26D: Investigated and no improvement can be made to the constraint equation at this stage.

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

Q_STR_43239_SMSF_38: Investigated and no improvement can be made to the constraint equation at this stage.

Q_STR_43239_HASF_40: Investigated and no improvement can be made to the constraint equation at this stage.

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

N^N_CHLS_1: 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 November 2019.

**Table 7 Generator and transmission changes**

| Project | Date | Region | Notes |
|---|---|---|---|
| Nil | Nil | Nil | Nil |

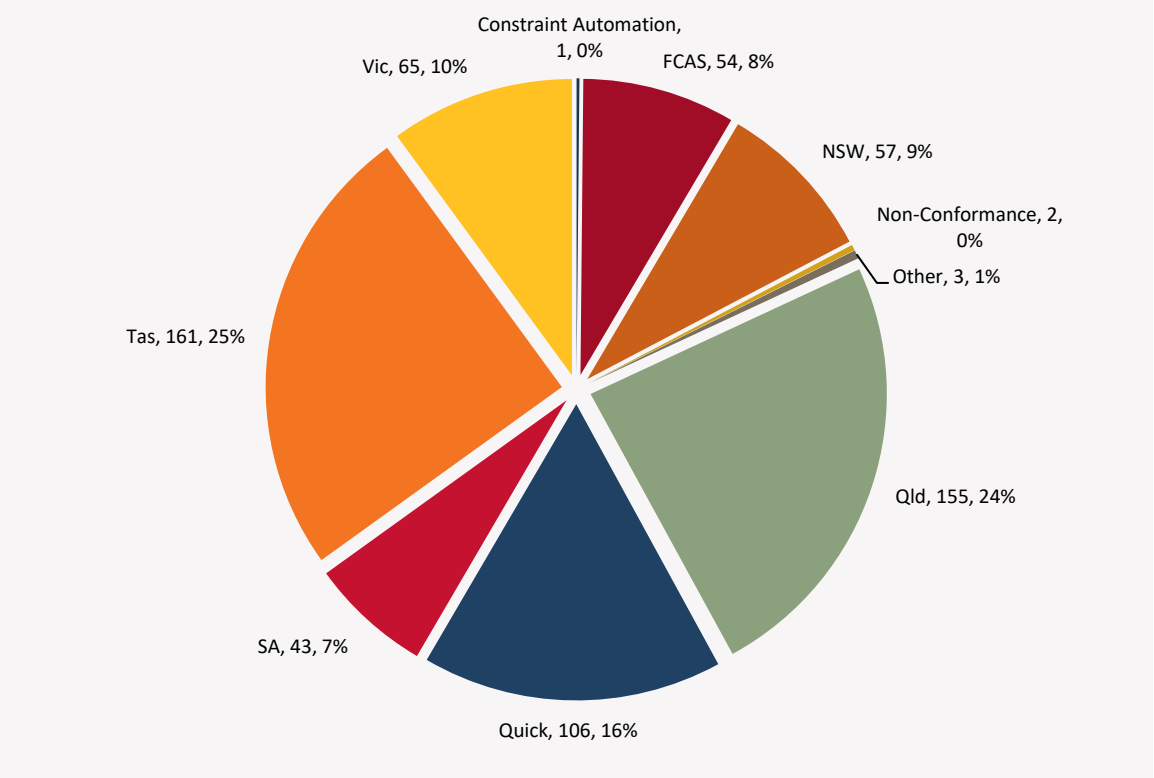
## 3.1 Constraint Equation Changes

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**