AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

# Monthly Constraint Report

## November 2021

A report for the National Electricity Market

# Important notice

## PURPOSE

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

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# 1. Introduction

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

# 2. Constraint Equation Performance

## 2.1 Top 10 binding constraint equations

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

**Table 1 Top 10 binding network constraint equations**

| Constraint Equation ID (System Normal Bold) | Description | #DIs (Hours) | Limit Type |
|---|---|---|---|
| SVML_ZERO | SA to Vic on ML upper transfer limit of 0 MW | 1391 (115.91) | Interconnector Zero |
| V^^N_LTYS_1 | Out = Lower Tumut - Yass (3) 330kV line , avoid voltage collapse around Murray for loss of all APD potlines | 1176 (98.0) | Voltage Stability |
| **N^^N_NIL_2** | Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback | 1135 (94.58) | Voltage Stability |
| **S>NIL_MHNW1_MHNW2** | Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback | 1107 (92.25) | Thermal |
| **Q>NIL_EMCM_6056** | Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder | 1096 (91.33) | Thermal |
| **N>>N-NIL_94T** | Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback | 1048 (87.33) | Thermal |
| 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 | 1043 (86.91) | System Strength |
| V_YATPSF_FLT_25 | Limit Yatpool solar farm upper limit to 25 MW to manage post contingent voltage oscillation | 970 (80.83) | System Strength |
| V_KARADSF_FLT_25 | Limit Karadoc solar farm upper limit to 25 MW to manage post contingent voltage oscillation | 968 (80.66) | System Strength |

| Constraint Equation ID (System Normal Bold) | Description | #DIs (Hours) | Limit Type |
|---|---|---|---|
| V_BANNERTSF_FLT_45 | Limit Bannerton Solar Farm upper limit to 45 MW to manage post contingent voltage oscillation | 838 (69.83) | System Strength |

## 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 | Limit Type |
|---|---|---|---|
| **N^^N_NIL_2** | Out=Nil , limit Darlington Point to Wagga line (63) line flow to avoid voltage collapse at Darlington Point 132kV post contingency trip of line 63, Feedback | 1,636,676 | Voltage Stability |
| **NRM_QLD1_NSW1** | Negative Residue Management constraint for QLD to NSW flow | 1,458,141 | Negative Residue |
| F_Q++LDTW_R6 | Out = Liddell to Tamworth (84) line, Qld Raise 6 sec Requirement | 1,238,446 | FCAS |
| **N>>N-NIL_94T** | Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback | 1,128,590 | Thermal |
| F_Q++LDTW_R60 | Out = Liddell to Tamworth (84) line, Qld Raise 60 sec Requirement | 1,118,527 | FCAS |
| 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 | 1,051,538 | System Strength |
| V_KARADSF_FLT_25 | Limit Karadoc solar farm upper limit to 25 MW to manage post contingent voltage oscillation | 981,717 | System Strength |
| **Q>NIL_EMCM_6056** | Out= NIL, avoid thermal overload on Emerald to Comet (6056) 66 kV Feeder | 904,467 | Thermal |
| N_BROKENH1_ZERO | Broken Hill Solar Farm upper limit of 0 MW | 869,177 | Unit Zero |
| V_BANNERTSF_FLT_45 | Limit Bannerton Solar Farm upper limit to 45 MW to manage post contingent voltage oscillation | 852,973 | System Strength |

## 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)

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.

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) | Limit Type |
|---|---|---|---|
| **NRM_QLD1_NSW1** | Negative Residue Management constraint for QLD to NSW flow | 173 (14.41) | Negative Residue |
| N_BROKENH1_0INV | Constraint to violate if Broken Hill Solar Farm inverter availability greater than zero. Constraint swamp out otherwise. DS only | 9 (0.75) | System Strength |
| NSA_V_NPSD_100 | Newport unit >= 100 MW for Network Support Agreement | 8 (0.66) | Network Support |
| NSA_V_BDL01_30 | Bairnsdale Unit 1 >= 30 MW for Network Support Agreement | 5 (0.41) | Network Support |
| F_Q++ARTW_L6 | Out = Armidale to Tamworth (85 or 86) line, Qld Lower 6 sec Requirement | 3 (0.25) | FCAS |
| **F_T+NIL_MG_RECL_R6** | Out = Nil, Raise 6 sec requirement for a Tasmania Reclassified Woolnorth Generation Event (both largest MW output and inertia), Basslink unable to transfer FCAS | 3 (0.25) | FCAS |
| NSA_V_BDL01_20 | Bairnsdale Unit 1 >= 20 MW for Network Support Agreement | 2 (0.16) | Network Support |
| 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 | 2 (0.16) | System Strength |
| **F_T+RREG_0050** | Tasmania Raise Regulation Requirement greater than 50 MW, Basslink unable to transfer FCAS | 1 (0.08) | FCAS |

## 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 |
|---|---|
| **NRM_QLD1_NSW1** | Constraint equation violated for 173 DIs, for up to 16 consecutive DIs, with max violation of 286.1 MW occurring on 08/11/2021 at 0935 hrs. Constraint equation violation occurred due to competing requirements with the export limits which were set by N^^Q_TW_330_BUS1_B1, N^^Q_ARTW_B1, F_Q++ARTW_R5, F_Q++LDMU_R6, F_Q++LDMU_R5, and N^N-LS_SVC. |
| N_BROKENH1_0INV | Constraint equation violated for 9 DIs, 7 of which were consecutive, on 01/11/2021 and 27/11/2021 with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit. |
| NSA_V_NPSD_100 | Constraint equation violated for 8 non-consecutive DIs on 25/11/2021 and 28/11/2021 with max violation of 68.88 MW occurring on 28/11/2021 at 0105 hrs. Constraint equation violation occurred due to Newport unit being limited by its start-up profile. |

| Constraint Equation ID (System Normal Bold) | Description |
|---|---|
| NSA_V_BDL01_30 | Constraint equation violated for 5 consecutive DIs on 30/11/2021 from 0605 hrs to 0625 hrs with max violation of 30 MW occurring on 30/11/2021 at 0605. Constraint equation violation occurred due to Bairnsdale unit being limited by its start-up profile. |
| F_Q++ARTW_L6 | Constraint equation violated for 3 DIs on 08/11/2021 at 1110, 1135, and 1140 hrs with max violation of 23.02 MW occurring at 1110 hrs. Constraint equation violation occurred due to Queensland lower 6 second availability being less than the requirement. |
| **F_T+NIL_MG_RECL_R6** | Constraint equation violated for 3 DIs on 14/11/2021 at 1500 hrs and 14/11/2021 at 0340 and 1300 hrs with max violation of 15.83 MW occurring on 14/11/2021 at 0340 hrs. Constraint equation violation occurred due to Tasmania raise 6 second availability being less than the requirement. |
| NSA_V_BDL01_20 | Constraint equation violated for 2 DIs on 30/11/2021 at 1500 hrs and 1505 hrs with max violation of 20 MW occurring at 1505 hrs. Constraint equation violation occurred due to Bairnsdale unit tripping offline. |
| N_BKHSF_44INV | Constraint equation violated for 2 DIs on 01/11/2021 at 0405 and 0410 hrs with violation degree of 0.001 MW. Constraint equation violation occurred due to Broken Hill Solar Farm exceeding its inverter limit. |
| **F_T+RREG_0050** | Constraint equation violated for 1 DI on 14/11/2021 at 0340 hrs with violation degree of 1.21 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) |
|---|---|---|---|---|
| **F_MAIN++NIL_MG_R6** | T-V-MNSP1 Export | Out = Nil, Raise 6 sec requirement for a Mainland Generation Event, Basslink able transfer FCAS | 1274 (106.17) | 315.14 (454.01) |
| SVML_ZERO | V-S-MNSP1 Import | SA to Vic on ML upper transfer limit of 0 MW | 1204 (100.33) | 0.0 (0.0) |
| V^^N_LTYS_1 | VIC1-NSW1 Export | Out = Lower Tumut - Yass (3) 330kV line , avoid voltage collapse around Murray for loss of all APD potlines | 1146 (95.5) | 613.94 (1277.51) |
| **S>NIL_MHNW1_MHNW2** | V-S-MNSP1 Export | Out= Nil, avoid O/L Monash-North West Bend #2 132kV on trip of Monash-North West Bend #1 132kV line, Feedback | 1095 (91.25) | 154.02 (213.13) |
| Q>>CPWO1_CPWO2_WUGG | NSW1-QLD1 Export | Out= Calliope River to Woolooga (813) line Tee Gin Gin (section 1 or 2 or both), avoid O/L Calliope River to Woolooga (814) on trip of Wurdong to Teebar Creek (819) line, Feedback | 764 (63.67) | -380.23 (444.78) |
| V^SML_BUDP_3 | V-S-MNSP1 Export | 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 | 674 (56.17) | 0.41 (149.72) |

| Constraint Equation ID (System Normal Bold) | Interconnector | Description | #DIs (Hours) | Average Limit (Max) |
|---|---|---|---|---|
| **N^^N_NIL_3** | VIC1-NSW1 Export | Out= Nil, limit power flow on line X5 from Balranald to Darlington Point (X5) to avoid voltage collapse at Balranald for contingency trip of any major 220kV line in NW Victoria | 666 (55.5) | 66.62 (923.51) |
| 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 | 562 (46.83) | -58.06 (3.59) |
| **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 | 559 (46.58) | -259.4 (-454.0) |
| V^^N_DPWG_X5_1 | VIC1-NSW1 Export | Out = DarlingtonPt to Wagga(63) and Darlington Point to Balranald (X5) off loaded, avoid voltage collapse around Murray for loss of all APD potlines | 542 (45.17) | 689.67 (1055.58) |

## 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 3 – Non-Real-Time Constraint Automation usage

| Constraint Set ID | Date Time | Description |
|---|---|---|
| CA_BRIS_50B292E2 | 26/11/2021 08:00 to 26/11/2021 14:40 | This constraint automation was created to manage thermal overload of Upper Tumut – Lower Tumut 64 330 kV line during an outage of Lower Tumut - Yass 03 330 kV line for contingent trip of Lower Tumut – Canberra 07 0330 kV line. A new constraint has been created to manage this scenario in the future. |

### 2.5.1 Further Investigation

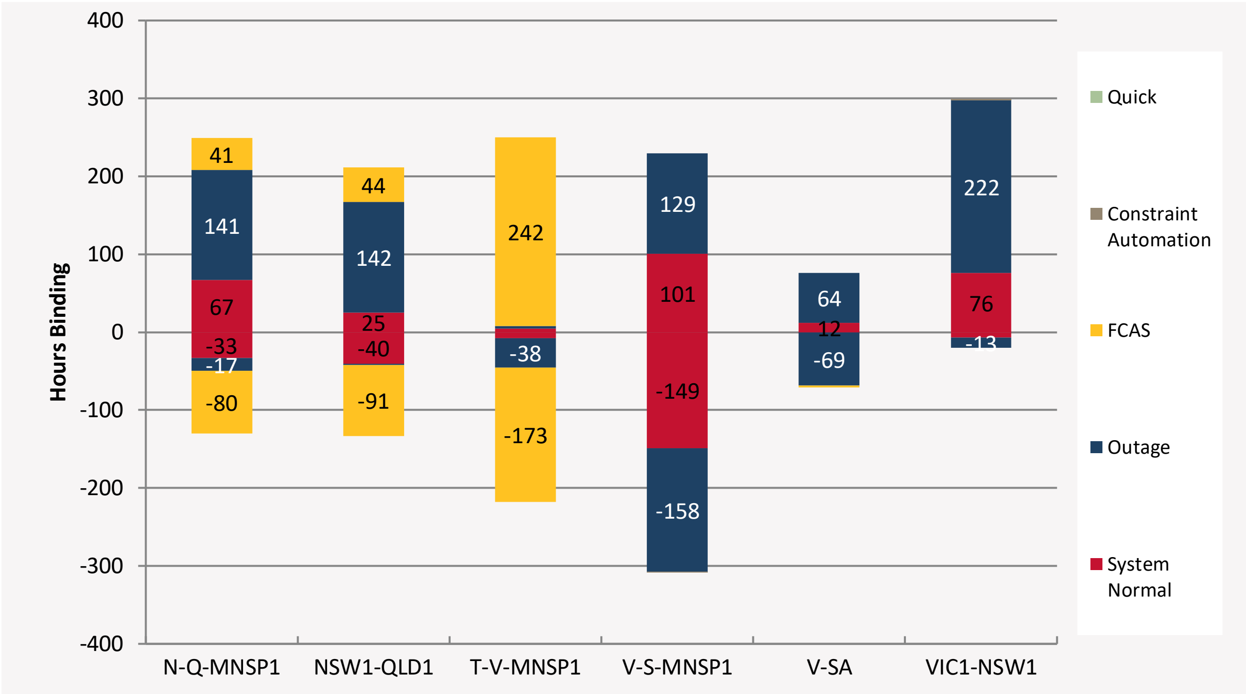
CA_BRIS_50B292E2: A new constraint has been created to manage this scenario in the future.

## 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.

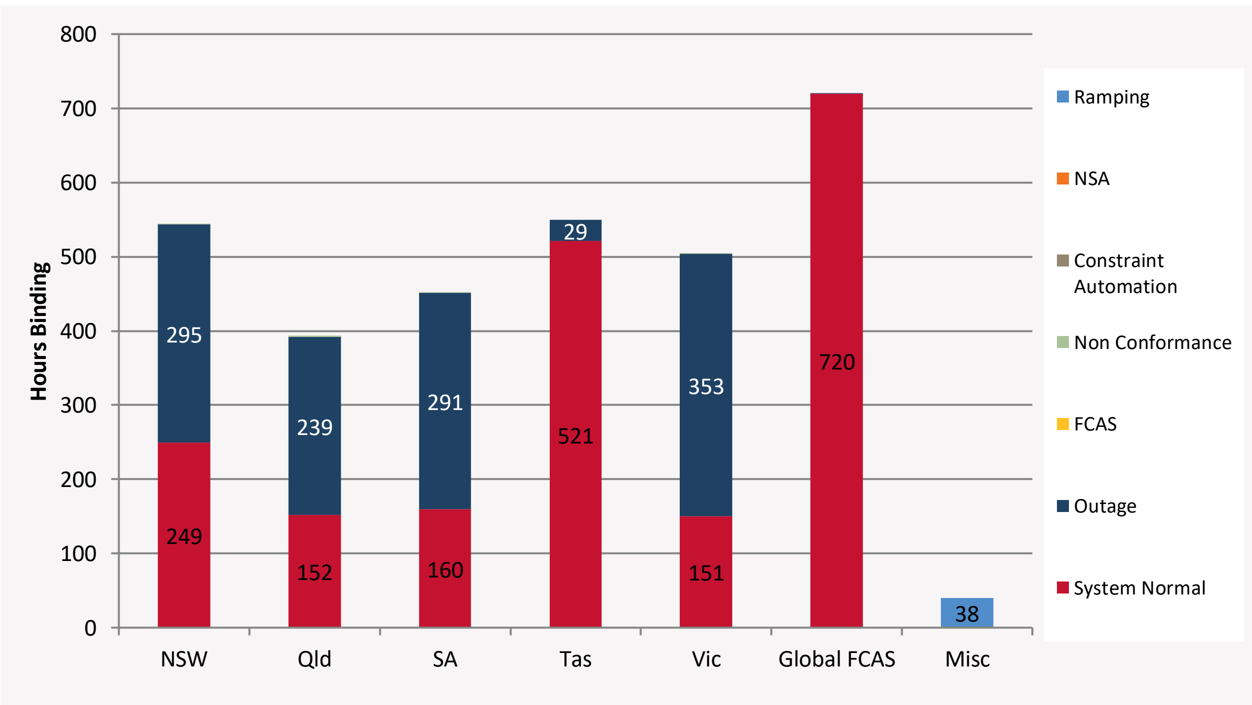
In the following graph the export binding hours are indicated as positive numbers and import with negative values.

**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.

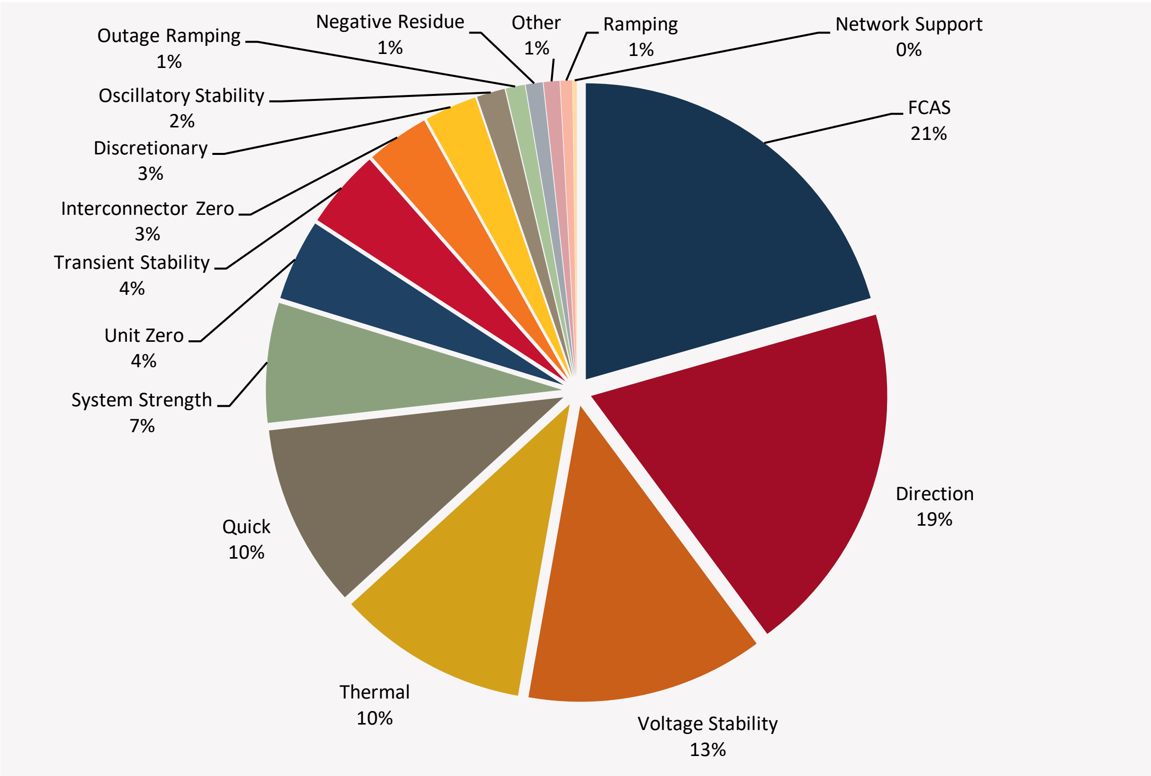
**Figure 2 Regional binding dispatch hours**



## 2.7 Binding Constraint Equations by Limit Type

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

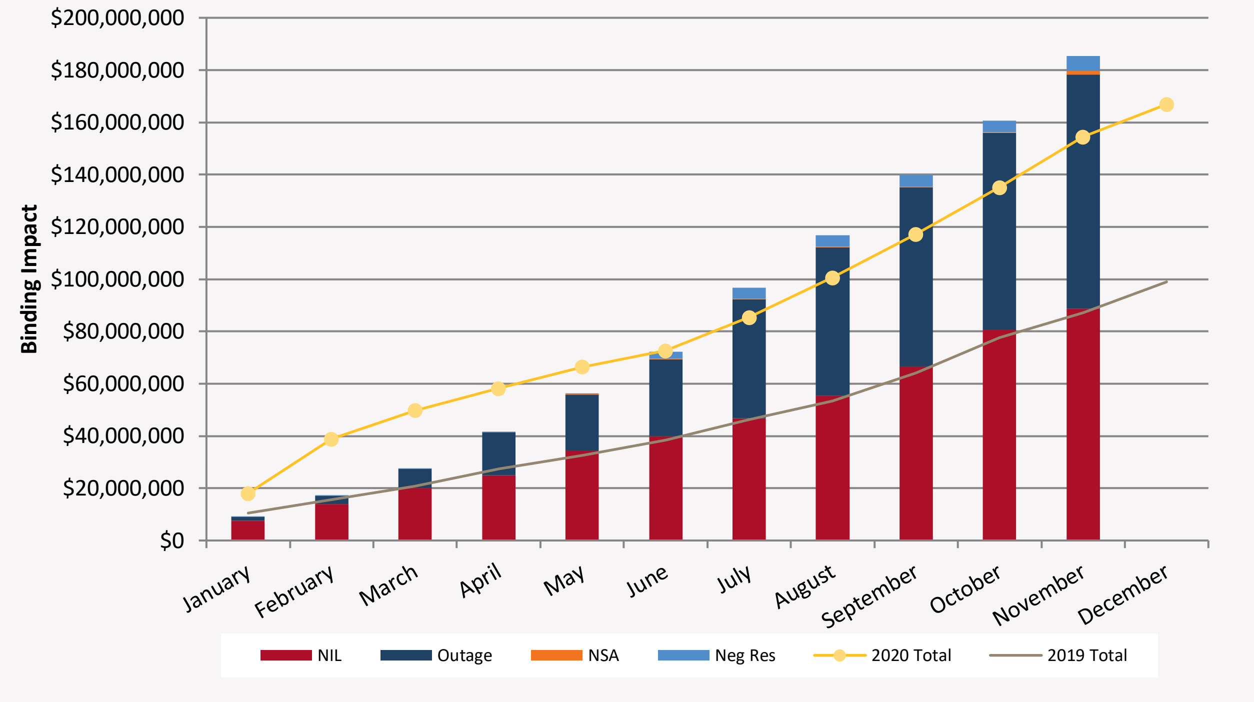
**Figure 3 Binding by limit type**




## 2.8 Binding Impact Comparison

The following graph compares the cumulative binding impact (calculated by summating the marginal values from the MCC re-run – the same as in section 2.2) for each month for the current year (indicated by type as a stacked bar chart) against the cumulative values from the previous two years (the line graphs). The current year is further categorised into system normal (NIL), outage, network support agreement (NSA) and negative residue constraint equation types.

**Figure 4 Binding Impact comparison**




## 2.9 Pre-dispatch RHS Accuracy

Pre-dispatch RHS accuracy is measured by the comparing the dispatch RHS value and the pre-dispatch RHS value forecast four hours in the future. The following table shows the pre-dispatch accuracy of the top ten largest differences for binding (in dispatch or pre-dispatch) constraint equations. This excludes FCAS constraint equations, constraint equations that violated in Dispatch, differences larger than ±9500 (this is to exclude constraint equations with swamping logic) and constraint equations that only bound for one or two Dispatch intervals. AEMO investigates constraint equations that have a Dispatch/Pre-dispatch RHS difference greater than 5% and ten absolute difference which have either bound for greater than 25 dispatch intervals or have a greater than $1,000 binding impact. The investigations are detailed in 2.9.1.

**Table 6 Top 10 largest Dispatch / Pre-dispatch differences**

| Constraint Equation ID (System Normal Bold) | Description | #DIs | % + Max Diff | % + Avg Diff |
|---|---|---|---|---|
| V::N_HWSM_S1 | 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, SA accelerates | 13 | 78,532% (389.23) | 6,226% (77.99) |
| 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 | 117 | 14,873% (104.19) | 532% (34.64) |
| V::N_LTWG_S2 | Out = Lower Tumut to Wagga 330kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 500 kV. | 13 | 7,111% (165.46) | 772% (70.12) |
| 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 | 176 | 2,750% (256.51) | 226% (60.48) |
| **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 for double-circuit loss of Heywood IC.Note: Constraint is swamped if UFLS blocks >= 1000 MW. | 140 | 2,146% (9,495) | 302% (857) |

| Constraint Equation ID (System Normal Bold) | Description | #DIs | % + Max Diff | % + Avg Diff |
|---|---|---|---|---|
| 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 | 6 | 2,139% (47.28) | 981% (31.09) |
| N_X_MBTE_3B | Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load | 33 | 1,560% (18.3) | 146.93% (6.26) |
| N_X_MBTE_3A | Out= all three Directlink cables, Terranora_I/C_import <= Terranora_Load | 23 | 1,560% (18.3) | 119.41% (6.08) |
| V::N_LTWG_S1 | Out = Lower Tumut to Wagga 330kV line, prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line, SA accelerates, Yallourn W G1 on 220 kV. | 15 | 1,139% (153.49) | 215% (81.52) |
| 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. | 11 | 1,015% (229.53) | 130.59% (78.15) |

### 2.9.1 Further Investigation

The following constraint equation(s) have been investigated:

V::N_LTWG_S2: Investigated and no improvement can be made to the constraint equation at this stage.

V::N_LTWG_S1: Investigated and no improvement can be made to the constraint equation at this stage.

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

V^SML_BUDP_3: Investigated and no improvement can be made to the constraint equation at this stage.

V_S_HEYWOOD_UFLS: Investigated and the Predispatch calculation has been updated to better model the South Australian inertia – including the addition of the four synchronous condensers.

N_X_MBTE_3B: Investigated and no improvement can be made to the constraint equation at this stage.

N_X_MBTE_3A: 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 2021.

**Table 7 Generator and transmission changes**

| Project | Date | Region | Notes |
|---|---|---|---|
| Sebastapol Solar Farm | 2 November 2021 | NSW1 | New Generator |
| Bolivar Battery | 16 November 2021 | SA1 | New Battery |
| Bolivar PV | 16 November 2021 | SA1 | New Generator |
| Western Downs Solar Farm | 16 November 2021 | QLD1 | New Generator |

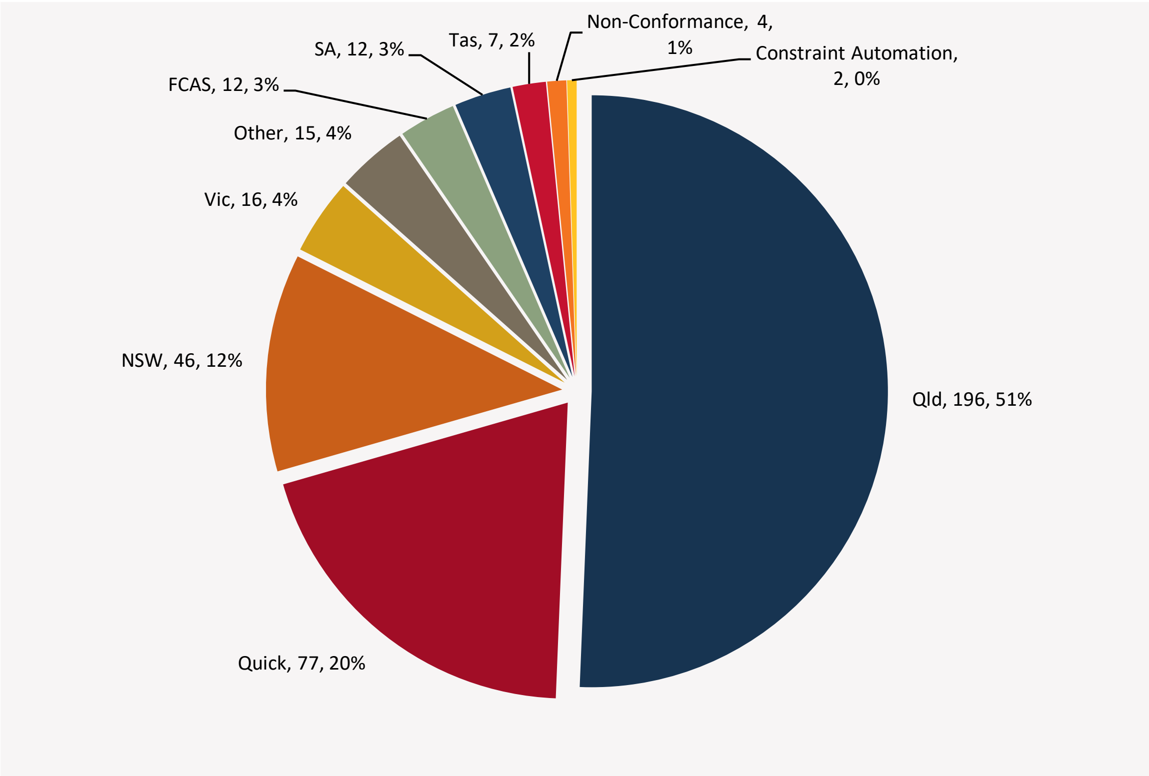
## 3.1 Constraint Equation Changes

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**