Victorian Transfer Limit Advice – Outages in Adjacent Regions

March 2021

For the National Electricity Market

Important notice

PURPOSE

AEMO has prepared this document to provide information about voltage and transient stability limits for flows to and from Victoria, as at the date of publication.

DISCLAIMER

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VERSION CONTROL

Version	Release date	Changes
3	12/03/2021	Update to offsets to Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines for outages in NSW
2		Added Stockdill to Upper Tumut outage
1	2/11/2020	Initial version – limits copied from the Vic single outages doc

Contents

Tables

1. Introduction

AEMO is responsible for calculating the maximum transient and voltage stability limits into and out of Victoria, voltage oscillation limits due to low system strength, as well as voltage unbalance constraints to keep the system within specified limits, in accordance with the National Electricity Rules (NER) S5.1.2.3 and the Power System Stability Guidelines[1]. This document describes the values for these transfer limits for single and multiple prior outage conditions in NSW and South Australia.

This limits advice document also describes the methodology used by AEMO to determine the transient and voltage stability limits, voltage oscillation and the voltage unbalance limits.

The limit equations for system normal cases are described in a separate document, *Victorian Transfer Limit Advice – System Normal*. Limit equations for single and multiple prior outages are described in *Victorian Transfer Limit Advice – Outages* and *Victorian Transfer Limit Advice – Multiple Outages*. These documents are available on the AEMO website[2].

1.1 Other AEMO publications

Other limit advice documents are located at: https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice

1.2 Calculating transient and voltage stability limits

Transfer limit equations are developed for power transfers into and out of Victoria (known as import and export limits respectively). Maximum export is limited by transient stability, whereas maximum import is determined by voltage stability.

Transient stability limit equations are derived from a large number of transient stability studies. Stability studies are based on the application of a 2-phase to ground fault at the most critical fault location.

Voltage stability limit equations are derived from a large number of load flow studies. Studies consider the trip of a large generator, the loss of Basslink when exporting from Tasmania (Tas.) to Victoria (Vic.), and where appropriate the fault and trip of a critical transmission line or transformer.

1.2.1 Methodology

The methodology for calculating voltage and transient stability limits is given below:

1. Generate a set of Power System Simulator for Engineering (PSS/E) cases to represent a wide range of operating conditions.
2. Execute a binary search algorithm to search for limiting interconnector power transfer.
3. Linear regression and statistical limit determination.

1.3 Calculating voltage unbalance limits

Voltage unbalance is based on the levels of negative sequence voltage. As specified in S5.1a.1 of the NER, the negative sequence voltage needs to be limited to 0.5% of nominal voltage for busbars greater than 100 kV. With the introduction of generation in the southwest of Victoria, AEMO has determined that under specific

[1] AEMO, *Power System Stability Guidelines*, Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Congestion-information,Viewed on 31 August 2016.

[2] Available at: https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice

outage conditions, the voltage unbalance at the Portland smelter (APD) 500 kV busbar can exceed these levels.

The limit equations are defined such that the simulated negative sequence voltage on the APD 500 kV bus does not exceed 0.4 % of nominal voltage[3] for system normal and prior circuit outage conditions. This allows for a margin of 0.1%, which is considered a minimum requirement to account for the following:

- Other sources of unbalance, including effect of loads and generation that were not represented. The simulation results only represent unbalance associated with the transmission network.
- Sufficient measurements of voltage unbalance in the APD area that are not presently available to enable verification or calibration of the simulation model.

As well, the maximum simulated voltage unbalance at APD without the additional generation in the south west of Victoria is 0.4%.

The voltage unbalance levels at APD are influenced by a combination of:

- Voltage balancing effect (or reduction of negative sequence voltage) at Mortlake caused by the Mortlake generators.
- Power flow and associated negative sequence voltage across the Mortlake (MOPS) to Moorabool (MLTS), and Mortlake (MOPS) to Heywood (HYTS) to APD No. 2 500 kV lines (which are not fully transposed).
- Power flow on the Moorabool (MLTS) to Tarrone (TRTS) to Heywood (HYTS) to APD No. 1 500 kV line and mutual coupling with the MOPS-MLTS and MOPS-HYTS-APD No. 2 500 kV lines.

These factors can produce additive or counteractive effects on negative sequence voltage at APD, depending on the direction of power flow in the MOPS-MLTS and MOPS-HYTS-APD No. 2 500 kV lines and adjacent MLTS-TRTS-HYTS-APD No. 1 500 kV line.

1.3.1 Methodology

A number of voltage unbalance simulations were performed using a Power Systems Computer Aided Design (PSCAD) model of the 500 kV network. From these results, limit equations were produced to keep the level of voltage unbalance at APD at or below 0.4% during specific outages on the 500 kV network. These equations quantify the relationship between generation, Vic to SA transfer (via Heywood), and where relevant, APD load, such that the simulated voltage unbalance at APD will not exceed 0.4%.

It is assumed that the net APD load can vary between 405 MW to 615 MW, and Portland wind farm can generate up to 100 MW.

1.4 Calculating voltage oscillation limits

Voltage oscillations and associated instability can occur in parts of the power system that have low system strength, especially during prior outage conditions. To mitigate such oscillations in Western Victoria power system, voltage oscillatory stability limits are determined for low system strength conditions including prior outage conditions. Simulations of large disturbances such as two-phase to ground fault and trip of critical lines are undertaken using PSCAD to determine if the voltage oscillations occur in the power system post-contingency.

Large disturbance simulations of several operating conditions are undertaken to determine the limiting operating conditions of the power system which prevent voltage oscillations from occurring.

1.4.1 Methodology

Voltage oscillation stability limits were determined by performing electromagnetic-transient simulations using PSCAD on a model of the north-west Victorian and south-west NSW networks. Several possible power system

[3] Line to Line = 2 kV and Line to Neutral = 1.15 kV

scenarios including Murraylink power import and export conditions, wind farm and solar farm operating conditions, battery operating conditions and special protection schemes were considered in the simulations.

1.5 Conversion to Constraint Equations

This document does not describe how AEMO implements these limit equations as constraint equations in the National Electricity Market (NEM) market systems. That is covered in the Constraint Formulation Guidelines, Constraint Naming Guidelines and Constraint Implementation Guidelines. These documents are located in the Congestion Information Resource on the AEMO website:

https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource

2. NSW – Single Outages

Note: these limits are in addition to the limits provided by TransGrid for each of these outages.

2.1 Balranald to Buronga (X3) 220 kV line

The following limit equations are enabled during an outage of the Balranald to Buronga (X3) 220 kV line.

2.1.1 Voltage Stability – NSW to Vic

Largest Vic generator or Basslink trip

To manage the Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink or the loss of the largest Victorian generator, apply the following prior outage offset to the system normal equation NIL_VI_BLVG. Studies monitored post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ [-1 * Sum [Term Values * System Normal Coefficients]] + Offset*

Table 1 N^V BALR-BSS_BLVG offset

Term	Offset
Offset to system normal equation NIL_VI_BLVG	-60

Dederang to Murray 330 kV line trip

The system normal voltage stability equation NIL_VI_BLVG will manage voltage stability associated with the loss of a Dederang to Murray 330 kV line. Therefore, no additional offset is required.

2.1.2 Voltage Stability - Murraylink

To manage the Murraylink voltage stability export limit from Victoria to SA for fault and trip of the Bendigo to Kerang 220 kV line, apply the following prior outage limit equations. Studies assume the Red Cliffs Voltage source controller (VSC) is in voltage control mode with the Very Fast Runback (VFRB) scheme disabled. Studies monitored post-contingent voltages and reactive power margin in southern NSW and the Victorian state grid. The limit equation is of the form:

*Victoria to SA (Murraylink) ≤ Sum [Term Values * Coefficients]*

Table 2 V^S [MRLK] BALR-BSS_BEKG

Term	Coefficient
Intercept	242.8
RCTS Load	-1.242
KGTS Load	-1.939
BKNH TX MW	-0.9566
HOTS SVC Out of Service	-36
Confidence Level (95%) offset	-40

2.1.3 Voltage Oscillation

To prevent voltage oscillations for the trip of Ararat to Waubra to Ballarat or Bendigo to Kerang 220 kV line the following limits are applied:

Bannerton solar farm ≤ 45 MW

Bulgana wind farm ≤ 0 MW (can be operated in 'Pause Mode')

Bulgana battery = 0 MW with all inverters disconnected.

Coleambally solar farm ≤ 50 MW

Darlington Point solar farm ≤ 100 MW

Finley solar farm ≤ 50 MW

Gannawarra solar farm ≤ 30 MW

Horsham SVC switched off or set to manual mode with a fixed Q setpoint

Karadoc solar farm ≤ 25 MW

Kiamal solar farm ≤ 50 MW

Murra Warra wind farm ≤ 90 MW

Murraylink SA-VIC ≤ 130 MW

Wemen solar farm ≤ 45 MW

Yatpool solar farm ≤ 25 MW

2.2 Balranald to Darlington Point (X5) 220 kV line

The same limits applied for Balranald to Buronga (X3) apply for this outage (refer to section 2.1).

2.3 Canberra to Capital (6) 330 kV line

The following limit equations are enabled during an outage of the Canberra to Capital (6) 330 kV line.

2.3.1 Voltage Stability – NSW to Vic

To manage the Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink or the loss of the largest Victorian generator, apply the following prior outage offset to the system normal equation NIL_VI_BLVG. Studies monitored post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ [-1 * Sum [System Normal Term Values * System Normal Coefficients]] + Offset*

Table 3 V^N CANB-CAP_BLVG offset

Term	Offset
Offset to system normal equation NIL_VI_BLVG	-50

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 4 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-100

2.4 Canberra to Lower Tumut (7) 330 kV line

The following limit equation is enabled during an outage of the Marulan to Yass 330 kV line.

2.4.1 Voltage Stability – Vic to NSW

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 5 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-75

2.5 Capital to Kangaroo Valley (3W) 330 kV line

The following limit equations are enabled during an outage of the Capital to Kangaroo Valley (3W) 330 kV line.

2.5.1 Voltage Stability – NSW to Vic

To manage the Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink or the loss of the largest Victorian generator, apply the following prior outage offset to the system normal equation NIL_VI_BLVG. Studies monitored post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ [-1 * Sum [System Normal Term Values * System Normal Coefficients]] + Offset*

Table 6 V^N CANB-CAP_BLVG offset

Term	Offset
Offset to system normal equation NIL_VI_BLVG	-50

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 7 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-100

2.6 Collector to Marulan (4) 330 kV line

The following limit equation is enabled during an outage of the Marulan to Yass 330 kV line.

2.6.1 Voltage Stability – Vic to NSW

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 8 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-100

2.7 Collector to Yass (3L) 330 kV line

The same limits applied for Collector to Marulan (4) apply for this outage (refer to section 2.6).

2.8 Darlington Point to Wagga (63) 330 kV line

The following limits are enabled during an outage of the Darlington Point to Wagga (63) 330 kV line.

2.8.1 Voltage Oscillation

To prevent voltage oscillations for the trip of the Ararat to Waubra to Ballarat or Bendigo to Kerang 220 kV line the following limits are applied:

When the line X5 (Balranald-Darlington Point) is opened.

Bannerton solar farm ≤ 45 MW

Bulgana wind farm ≤ 0 MW (can be operated in 'Pause Mode')

Bulgana battery = 0 MW with all inverters disconnected.

Coleambally solar farm ≤ 50 MW

Finley solar farm ≤ 50 MW

Gannawarra solar farm ≤ 30 MW

Horsham SVC switched off or set to manual mode with a fixed Q setpoint

Karadoc solar farm ≤ 25 MW

Kiamal solar farm ≤ 50 MW

Murra Warra wind farm ≤ 90 MW

Murraylink SA-VIC ≤ 130 MW

Wemen solar farm ≤ 45 MW

Yatpool solar farm ≤ 25 MW

When the line X5 (Balranald-Darlington Point) is in service.

Bannerton solar farm ≤ 45 MW

Bulgana wind farm ≤ 0 MW (can be operated in 'Pause Mode')

Bulgana battery = 0 MW with all inverters disconnected.

Gannawarra solar farm ≤ 30 MW

Horsham SVC switched off or set to manual mode with a fixed Q setpoint

Karadoc solar farm ≤ 25 MW

Kiamal solar farm ≤ 50 MW

Murra Warra wind farm ≤ 90 MW

Murraylink SA-VIC ≤ 130 MW

Wemen solar farm ≤ 45 MW

Yatpool solar farm ≤ 25 MW

2.8.2 Voltage Stability – Vic to NSW

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 9 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-100

For Darlington Point to Wagga (63) 330 kV line outage, if X5 (Balranald to Darlington Point 220 kV) is also out of service the limit equation is of the form following:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 10 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-200

2.9 Gullen Range to Yass (3J) 330 kV line

The following limit equations are enabled during an outage of the Gullen Range to Yass 330 kV line.

2.9.1 Voltage Stability – NSW to Vic

To manage the Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink or the loss of the largest Victorian generator, apply the following prior outage offset to the system normal equation NIL_VI_BLVG. Studies monitored post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ [-1 * Sum [System Normal Term Values * System Normal Coefficients]] + Offset*

Table 11 V^N GULL-YASS_BLVG offset

Term	Offset
Offset to system normal equation NIL_VI_BLVG	-50

2.10 Jindera to Wagga (62) 330 kV line

The following limit equations are enabled during an outage of the Jindera to Wagga 330 kV line.

Note : Balranald to Darlington Point (X5) line is also out of service for this outage and the limits for an X5 outage also apply (see section 2.2).

2.10.1 Transient Stability – Vic to NSW

To manage the Victorian transient stability export limit from Victoria to NSW for fault and trip of a Hazelwood to South Morang 500 kV line, apply the following prior outage offsets to system normal equations NILV, NILQ, NILS and NILS decelerating. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * System Normal Coefficients] + Offset*

Table 12 V::N HOTS-RCTS_V/Q/S/S_decel offsets

Term	Offset
Offset to system normal equation NILV	-50
Offset to system normal equation NILQ	0
Offset to system normal equation NILS	-50
Offset to system normal equation NILS_decel	-50

2.10.2 Voltage Stability – NSW to Vic

Largest Vic generator or Basslink trip

To manage the Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink or the loss of the largest Victorian generator, apply the following prior outage offset to the system normal equation NIL_VI_BLVG. Studies monitored post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ [-1 * Sum [Term Values * System Normal Coefficients]] + Offset*

Table 13 V^N JIND-WAGGA_BLVG offset

Term	Offset
Offset to system normal equation NIL_VI_BLVG	-60

Dederang to Murray 330 kV line trip

The system normal voltage stability equation NIL_VI_BLVG will manage voltage stability associated with the loss of a Dederang to Murray 330 kV line. Therefore no additional offset is required.

2.10.3 Voltage Oscillation

To prevent voltage oscillations for the trip of Ararat to Waubra to Ballarat or Bendigo to Kerang 220 kV line the voltage oscillation limits for the Dederang to Wodonga 330 kV are applied (see Vic Transfer Limit Advice – Outages).

2.11 Lower Tumut To Murray (66) 330 kV line

The following limit equations are enabled during an outage of the Lower Tumut to Murray 330 kV line.

2.11.1 Transient Stability – Vic to NSW

V::N LTSS-MSS_V

To manage the Victorian transient stability export limit from Victoria to NSW for fault and trip of the Murray to Upper Tumut 330 kV line (where Victoria accelerates ahead of the other states), apply the following limit equation:

*Victoria to NSW ≤ Sum [Term Values * Coefficients]*

Table 14 V::N LTSS-MSS_V coefficients

Term	Coefficient
Intercept	1013
Basslink	0.07939
Vic. to SA (Heywood)	0.03878
Vic. to SA (Heywood)^2	-1.855e-4
Vic. to SA (Murraylink)	-0.5962
LV 500 Inertia	1.051
EPS Inertia	7.054
SNOWY Inertia	1.862
Murray Gen	0.1849
Kiewa Gen	0.2187
LV 220 Gen	0.1088
VIC Metro Gen	0.1639
State Grid Load North	-0.3499
Vic Wind & Solar	0.05988
VIC Demand - State Grid Load North	-0.05126
220 kV Caps	-0.07045
Num. ROTS SVC	14.09
Confidence Level (95%) offset	-60

V::N LTSS-MSS_S

To manage the Victorian transient stability export limit from Victoria to NSW for fault and trip of the Murray to Upper Tumut 330 kV line (where Victoria accelerates ahead of the other states), apply the following limit equation:

*Victoria to NSW ≤ Sum [Term Values * Coefficients]*

Table 15 V::N LTSS-MSS_S coefficients

Term	Coefficient
Intercept	938
Basslink	0.05857
Vic. to SA (Heywood)^2	-1.279e-4
Vic. to SA (Murraylink)	-0.4675
LV 500 Inertia	0.9008
SNOWY Inertia	1.973
VIC METRO Gen Inertia	1.407
Murray Gen	0.1011
Kiewa Gen	0.2234
LV 220 Gen	0.04787
State Grid Load North	-0.1881
Vic Wind & Solar	0.06093
VIC Demand - State Grid Load North	-0.03251
Num. ROTS SVC	13.74
Confidence Level (95%) offset	-68

2.11.2 Voltage Stability – NSW to Vic

The system normal voltage stability equation NIL_VI_BLVG will manage voltage stability associated with the fault and trip of Basslink, the loss of the largest Victorian generator or the loss of a Murray to Upper Tumut 330 kV line. Therefore no additional offset is required.

2.12 Lower Tumut To Upper Tumut (64) 330 kV line

The following limit equations are enabled during an outage of the Lower Tumut to Upper Tumut 330 kV line.

2.12.1 Voltage Stability – NSW to Vic

The system normal voltage stability equation NIL_VI_BLVG will manage voltage stability associated with the fault and trip of Basslink, the loss of the largest Victorian generator or loss of a Murray to Upper Tumut 330 kV line. Therefore no additional offset is required.

2.13 Lower Tumut to Wagga (051) 330 kV line

The following limit equations are enabled during an outage of the Lower Tumut to Wagga 330 kV line.

2.13.1 Transient Stability – Vic to NSW

To manage the Victorian transient stability export limit from Victoria to NSW for fault and trip of a Hazelwood to South Morang 500 kV line, apply the following prior outage offsets to system normal equations NILV, NILQ, NILS and NILS decelerating. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * System Normal Coefficients] + Offset*

Table 16 V::N LTSS-WAGGA_V/Q/S/S_decel offsets

Term	Offset
Offset to system normal equation NILV	-30
Offset to system normal equation NILQ	0
Offset to system normal equation NILS	-30
Offset to system normal equation NILS_decel	-30

2.13.2 Voltage Stability – NSW to Vic

To manage Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink, the loss of the largest Victorian generator or loss of a Dederang to Murray 330 kV line., apply the following limit equation. Studies monitor post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ -1 * Sum [Term Values * Coefficients]*

Table 17 V^N LTSS-WAGGA BLVG coefficients

Term	Coefficient
Intercept	-1369
Contingent_MW	0.9359
SW_NSW	0.7477
NSWd-SW_NSW	0.008493
STH_NSW_GEN	-0.08801
UTUM1SC+UTUM2SC	-24.27
LTUM3SC	-55.16
MSS2SC	-60.74
DD330Cap	-0.3148
WAGGACap	-0.2354
DLPTShunt	-0.6063
MSSReac	-0.2601
YASSReac	-0.1681
U_TUMUT_Gen	-0.4624
L_TUMUT_Gen	-0.1718
MURRAY_Gen	0.5303
UQT Gen	-0.7286
HUME VIC GEN	-3.360
BKNH_GEN	-1.074
Num. MSS1 on	-18.59
Confidence Level (95%) offset	+83.3

2.14 Lower Tumut to Yass (3) 330 kV line

The following limit equations are enabled during an outage of the Lower Tumut to Yass 330 kV line.

2.14.1 Voltage Stability – NSW to Vic

To manage the Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink or the loss of the largest Victorian generator, apply the following prior outage offset to the system normal equation NIL_VI_BLVG. Studies monitored post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ [-1 * Sum [System Normal Term Values * System Normal Coefficients]] + Offset*

Table 18 V^N LTSS-YASS_BLVG offset

Term	Offset
Offset to system normal equation NIL_VI_BLVG	-50

2.15 Marulan to Yass (5) 330 kV line

The same limits applied for Collector to Marulan (4) apply for this outage (refer to section 2.6).

2.16 Murray To Upper (65) Tumut 330 kV line

The following limit equations are enabled during an outage of the Murray to Upper Tumut 330 kV line.

2.16.1 Transient Stability – Vic to NSW

To manage the Victorian transient stability export limit from Victoria to NSW for fault and trip of the Lower Tumut to Murray to 330 kV line (where Victoria accelerates ahead of the other states), apply the limit equations in section (see 0) and (see 0).

2.16.2 Voltage Stability – NSW to Vic

Largest Vic generator or Basslink trip

To manage the Victorian voltage stability import limit from NSW to Victoria for fault and trip of Basslink or the loss of the largest Victorian generator, apply the following prior outage offset to the system normal equation NIL_VI_BLVG. Studies monitored post-contingent voltages and reactive power margin in northern Victoria and southern NSW. The limit equation is of the form:

*NSW to Victoria ≤ [-1 * Sum [Term Values * System Normal Coefficients]] + Offset*

2.16.3 Voltage Stability – Vic to NSW

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 19 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-200

Table 20 V^N MSS-UTSS_BLVG offsets

Term	Offset
Offset to system normal equation NILV	-120

Lower Tumut to Murray 330 kV line trip

The system normal voltage stability equation NIL_VI_BLVG will manage voltage stability associated with the loss of a Lower Tumut to Murray 330 kV line. Therefore no additional offset is required.

2.17 Ravine to Yass (2) 330 kV line

The following limit equation is enabled during an outage of the Upper Tumut to Yass 330 kV line.

2.17.1 Voltage Stability – Vic to NSW

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-50

2.18 Stockdill to Upper Tumut (1) 330 kV line

The same limits applied for Canberra to Capital (6) apply for this outage (refer to section 2.3)

2.19 Upper Tumut to Ravine (6X) 330 kV line

The following limit equation is enabled during an outage of the Upper Tumut to Yass 330 kV line.

2.19.1 Voltage Stability – Vic to NSW

To manage the Vic to NSW voltage stability export limit from Victoria to NSW for loss of both APD Potlines, apply the following prior outage offset to the system normal equation V^N_2xAPD. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * Coefficients] +Offset*

Table 21 V^N_2xAPD offset

Term	Offset
Offset to system normal V^N_2xAPD	-50

3. South Australia - Single Outages

Note: these limits are in addition to the limits provided by ElectraNet for each of these outages.

3.1 South East to Tailem Bend 275 kV line

The following limit equations are enabled during an outage of one South East to Tailem Bend 275 kV line.

3.1.1 Transient Stability – Vic to NSW

To manage the Victorian transient stability export limit from Victoria to NSW for fault and trip of a Hazelwood to South Morang 500 kV line, apply the following prior outage offsets to system normal equations NILV, NILQ, NILS and NILS decelerating. The limit equation is of the form:

*Victoria to NSW ≤ Sum [Term Values * System Normal Coefficients] + Offset*

Table 22 V::N SESS-TAIL_V/Q/S/S_decel offsets

Term	Offset
Offset to system normal equation NILV	-50
Offset to system normal equation NILQ	0
Offset to system normal equation NILS	-50
Offset to system normal equation NILS_decel	-50

A1. Measures and Definitions

Units of Measure

Abbreviation	Unit of measure
kV	Kilovolt
MVA	Megavolt amperes
MVAR	Megavolt amperes reactive
MW	A Megawatt (MW) is one million watts. A watt (W) is a measure of power and is defined as one joule per second and it measures the rate of energy conversion or transfer.
MW.sec	Megawatt seconds – a measure of the inertia of a generating unit.

Parameter Definitions

Abbreviation	Definition
220 kV Caps	MVAR output from capacitors connected at 220 kV busbars (i.e. Altona, Brooklyn, Dederang, Fishermans Bend, Keilor, Moorabool, Rowville, Ringwood, Templestowe and Thomastown)
APD–HYTS_MVAR	Alcoa Portland smelter (APD) reactive power export (measured at 500 kV feeders). A negative value indicates that APD is importing MVAr.
APD–HYTS_MW	APD real power export (measured at 500 kV feeders. A negative value indicates that APD is importing MW).
APD Load	APD MW load at 33 kV and 22 kV
APD Net Load	Net load measured at APD 500kV bus (Actual APD load consumption – Portland wind farm generation)
BANReac	MVAR output of Bannaby reactors. Values associated with this term are negative.
Basslink	MW flow on the Basslink interconnector (measured at the receiving end)
BATS TX MW	MW flow through 220/66kV transformers at Ballarat (measured at HV side, positive value indicates load MW)
BETS Load	Bendigo (BETS) customer load (MW)
BHSS220 Load	Broken Hill 220 kV MW industrial (mine) load
BKNH GEN	MW output from Broken Hill Generation

Abbreviation	Definition
BKNH TX MW	MW flow through 220/22kV transformers at Broken Hill (measured at HV side, positive value indicates load MW)
BOPS+MKPS GEN	MW output from Bogong and McKay Power Station [BOPS & MKPS].
Both TAIL-SESS Series Caps Out	Both Tailem Bend – South East series caps out of service (1= Both series caps are out of service)
BRGAshnt	MVAR output of Buronga shunt devices. Values associated with this term can be positive or negative
CANCap	MVAR output of Canberra 220 kV capacitor banks. Values associated with this term are positive.
CMACap	MVAR output of Cooma capacitor banks. Values associated with this term are positive.
Constraint equation	These are the mathematical representations that AEMO uses to model power system limitations and FCAS requirements in National Electricity Market Dispatch Engine (NEMDE).
Contingent MW	Maximum of: a) MW Transfer from Tas to Vic via Basslink (measured at Loy Yang). Values associated with this term are positive for flows from Tas to Vic. b) MW output of a single generating unit in Vic (MW associated with the contingency: Loss of the Largest Generator). Values associated with this term are positive.
CUECap	MVAR output of Queanbeyan capacitor banks. Values associated with this term are positive.
DD220Cap	MVAR output of Dederang 220 kV capacitor banks. Values associated with this term are positive.
DD330Cap	MVAR output of Dederang 330 kV capacitor banks. Values associated with this term are positive.
DLPTshunt	MVAR output of Darlington Point shunt devices. Values associated with this term can be positive or negative
DPS GEN	MW output from Dartmouth Power Station [DPS].
EPS Inertia	Inertia from Eildon Power Station (EPS). Inertia is on a 100 MVA base (MW.sec / 100 MVA) as per EMS.
GEN EPS on	Number of Eildon Power station (EPS) units online.
GEN DPS on	Number of Dartmouth Power station units online [DPS].
GEN BOPS on	Number of Bogong Power station units online [BOPS].
GEN MKPS on	Number of Mckay Power station units online [MKPS].
GEN WKPS on	Number of West Kiewa Power station units online [WKPS].
Guthega GEN	MW output from Guthega Power Station [GGA].
Guthega Inertia	Inertia from Guthega Power Station [GGA]. Inertia is on a 100 MVA base (MW.sec / 100 MVA) as per EMS.
HOTS Load	Horsham (HOTS) customer load (MW)
HOTS SVC out of service	Horsham SVC out of service, This term is equal to 0 when the SVC is in service, and equal to 1 when the SVC is out of service.
HUME VIC GEN	MW output from Hume Power station (Victorian connection)
HYTS_CAP_Status	Heywood capacitor status (1 = capacitor in service).
JBE Pump	MW at Jindabyne Power Station [JBE]. Values associated with this term are negative.

Abbreviation	Definition
KGTS Load	Kerang (KGTS) customer load (MW)
KGTS SVC out of service	Kerang SVC out of service, This term is equal to 0 when the SVC is in service, and equal to 1 when the SVC is out of service.
Kiewa Gen	MW output from Kiewa hydro scheme generators (Bogong, Clover, Dartmouth, Mckay and West Kiewa).
Kiewa Inertia	Inertia from Kiewa hydro scheme generators (Bogong, Clover, Dartmouth, McKay and West Kiewa). Inertia is on a 100 MVA base (MW.sec / 100 MVA).
L_TUMUT_Gen	MW output from Lower Tumut 3 power station (LTSS). Values associated with this term can be positive or negative due to the ability of Lower Tumut units to operate in pumping mode
LTUM3SC	Number of generator units operating as synchronous condensers at Lower Tumut.
LV 220 Gen	MW output from Latrobe Valley generation on the 220 kV network (Yallourn W2, 3, and 4, and Yallourn unit 1 when connected to the 220 kV network).
LV 220 Inertia	Inertia associated with Latrobe Valley generation on the 220 kV network (Yallourn W2, 3, and 4, and Yallourn unit 1 when connected to the 220 kV network).
LV 500 Inertia	Inertia associated with Latrobe Valley generation on the 500 kV network (Loy Yang (A, B, and Valley Power), Jeeralang, Bairnsdale, and Yallourn W unit 1 when connected to the 500 kV network).
MCAR_Gen	MW output from the Macarthur Wind Farm (MCAR).
MLTS_220_Reactors	Count of MLTS 220 kV reactors.
MLTS_Line_Reactors	Count of MLTS line reactors (2=both reactors in service).
MMWF_Gen	MW output from the Mount Mercer Wind Farm (MMWF).
MOPS Inertia	Inertia from Mortlake Power Station (MOPS). Inertia is on a 100 MVA base (MW.sec / 100 MVA) as per EMS.
MSS2SC	Number of generator units operating as synchronous condensers at Murray 2.
MSSReac	MVAR output of Murray reactors. Values associated with this term are negative.
Murray Gen	MW output from Murray Power Station (Murray 1 and Murray 2).
Num. MSS1 on	Number of generator units operating at Murray 1.
Num. ROTS SVC	Number of Static Var Compensators (SVCs) at Rowville in service.
Num. SESS SVC	Number of SVCs at South East in service.
NSW_D	New South Wales demand
NSWd- SW_NSW	NSW demand (customer load + losses) minus the load in southern NSW.
NSW_H	Inertia of New South Wales generators excluding Murray, Lower Tumut and Upper Tumut (Eraring, Vales Point, Bayswater, Munmorah, Redbank, Mt Piper, Liddell, Bendeela, Kangaroo Valley, Colongra, Tallawarra, Uranquinty)
Parallel System	Victorian system operating in "Parallel" mode, This term is equal to 0 when operating in radial mode, and equal to 1 when operating in parallel mode.
Portland WF	Portland wind farm generation, MW

Abbreviation	Definition
QLD_H	Inertia of Queensland generators (Swanbank B, Gladstone, Tarong, Wivenhoe, Callide B, Stanwell, Callide C, Tarong North, Swanbank E, Barcaldine, Barron Gorge, Callide A, Collinsville, Invicta, Kareeya, Mackay, Mt Stuart, Townsville, Oakey, Millmerran, Braemar, Darling Downs, Condamine, Braemar 2, Kogan Creek)
RCTS Load	Red Cliffs (RCTS) customer load (MW)
Rowville SVC1 or SVC2 out of service	Rowville SVC out of service, This term is equal to 0 when the SVC is in service, and equal to 1 when one SVC is out of service.
SNOWY Inertia	Inertia from the Snowy area (Murray, Lower Tumut and Upper Tumut). Inertia is on a 100 MVA base (MW.sec / 100 MVA).
SNOWY_GSC_H	Inertia of Snowy generation (Murray, Guthega, Lower Tumut and Upper Tumut) minus the inertia of Lower Tumut machines running as pumps. Inertia is on a 100 MVA base (i.e. MW.sec / 100 MVA).
State Grid Load	Vic State Grid Load. This is the sum of the State Grid Load North (SGLN) and State Grid Load South (SGLS).
State Grid Load North	Vic State Grid Load north is the sum of load at the following bulk supply points: Bendigo (BETS), Fosterville (FVTS), Glenrowan (GNTS), Kerang (KGTS), Mt Beauty (MBTS), Red Cliffs (RCTS), Shepparton (SHTS), Wemen (WETS), and Wodonga (WOTS)
State Grid Load South	Vic State Grid Load south is the sum of load at the following bulk supply points: Ararat (ARTS), Ballarat (BATS), Horsham (HOTS), Stawell (STA) and Terang (TGTS).
SW_NSW	Load in Southern NSW is the sum of customer load at the following bulk supply points: Broken Hill (BKH_S1-22 and BKH-220), Gadara (GAD-11), Jounama (JOU-66), Darlington Point (DLP-132), Morven (MOR-132), Albury (ALB-132), AMN-132, Coleambally (CLY-132), Marulan (MRN-132, GOU-132), Wagga (WAN-132, WAN-66, WAW-132), Murrumburrah (MRU-66), Deniliquin (DNQ-66), Yass (YAS-66), Balranald (BRD-22), Finley (FNY-132), Griffith (GRF-132), Mulwala (MUL-132), Corowa (COR-132), and Yanco (YNC-33)
STH_NSW_GEN	Generation in southern NSW. Values associated with this term are positive. Generation in this region are Gullen Range WF, Gullen SF, Capital WF, Cullerin Range WF, Coleambally SF, Gunning WF, Boco Rock WF, Taralga WF, Woodlawn WF, Burrinjuck Hydro, Blowering Hydro, Gadara, and Jounama Hydro Embedded generation
System normal	The configuration of the power system where: a) All transmission elements are in service, or b) The network is operating in its normal network configuration.
TNSP	Transmission Network Service Provider
Tumut Pump	MW of Lower Tumut machines in pumping mode (this MW value is negative).
UQT Gen	MW output from Uranquinty (UQT) Power Station.
U_TUMUT_Gen	MW output from Upper Tumut 1 and Upper Tumut 2 Power Station (UTSS).
UTUM1SC+UTUM2SC	Number of generator units operating as synchronous condensers at Upper Tumut 1 and Upper Tumut 2.
V_MLTS5	MLTS 500 kV voltage (typical values between 450 and 550 kV).
V_MSS3330	Voltage (kV) at the Murray Power Station 330 kV bus.
VIC220_Gen	MW output from Latrobe Valley generation on the 220 kV network (Yallourn W units 2, 3 and 4 and unit 1 when connected to 220 kV network).
Vic Demand	Vic MW demand (calculated as generation minus export).
Vic to SA (Heywood)	MW transfer from Vic to SA via Heywood (measured at South East end). The interconnector direction and lines it consists of follow the NEM standard.

Abbreviation	Definition
Vic to SA (Murraylink)	MW transfer from Vic to SA via Murraylink (measured at Red Cliffs end).
VIC to NSW	MW transfer from Vic to NSW
Vic Demand - State Grid Load	Vic Demand (MW) minus Vic State Grid Load (SGL).
Vic Demand - State Grid Load North – APD Load	Vic Demand (MW) minus Vic State Grid Load North (SGLN) minus APD Load.
Vic Metro Gen	MW output from Vic metropolitan generators (Newport, Somerton, and Laverton North).
Vic Metro Gen Inertia	Inertia from Vic metropolitan generators (Newport, Somerton and Laverton North). Inertia is on a 100 MVA base (MW.sec / 100 MVA) as per EMS.
Vic Wind & Solar	MW Generation from all Vic windfarms and solar plant. This includes Ararat WF, Bald Hills WF, Ballarat Battery (Gen Component), Bannerton SF, Bulgana WF, Challcum Hills WF, Crowlands WF, Gannawarra Battery (Gen component), Gannawarra SF, Karadoc SF, Kiata WF, Macarthur WF, Moorabool WF, Mortons Lane WF, Mount Gelibrand WF, Mount Mercer WF, Murra Warra WF, Numerkah SF, Oaklands Hill WF, Portland WF, Salt Creek WF, Waubra WF, Wemen SF, Yaloak South WF,Yambuk WF, Yatpool SF and Yendon SF
WAGGACap	MVAR output of Wagga Wagga capacitor banks. Values associated with this term are positive.
WKPS GEN	MW output from West Kiewa Power Station [WKPS].
WETS Load	Wemen (WETS) customer load (MW)
WOTSCap	MVAR output of Wodonga capacitor banks. Values associated with this term are positive.
YASSCap	MVAR output of Yass capacitor banks. Values associated with this term are positive.
YASSReac	MVAR output of Yass reactors. Values associated with this term are negative.

Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER). The NER meanings are adopted unless otherwise specified.

Term	Definition
Constraint equation	These are the mathematical representations that AEMO uses to model power system limitations and FCAS requirements in National Electricity Market Dispatch Engine (NEMDE).
System normal	The configuration of the power system where: • All transmission elements are in service, or • The network is operating in its normal network configuration
TNSP	Transmission Network Service Provider