INTERCONNECTOR CAPABILITIES

FOR THE NATIONAL ELECTRICITY MARKET

Published: **November 2017**

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document for the purposes of rule 3.13.3(p) of the National Electricity Rules to provide information about the normal capability of interconnectors and planned projects to increase this capability, as at the date of publication.

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VERSION RELEASE HISTORY

Version number	Release date	Author	Comments
3	3 November 2017	Ben Blake	Updated Heywood upgrade limits and augmentations in SA near Murraylink and western Victoria, updated to latest AEMO template, fixed links to new AEMO website, updated disclaimer.
2	September 2015	Magnus Hindsberger	Updated information about interconnector augmentations. Minor changes to text elsewhere.
1	July 2014	Ben Blake	Initial version

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1. INTRODUCTION

This document provides participants, prospective participants, and parties interested in the National Electricity Market (NEM), with information about the nominal capacity of the transmission lines that connect the various NEM regions (interconnectors), and information on planned or proposed upgrades to increase their capacity.

Specifically, it describes the nominal capacity of the interconnectors when there are no transmission outages. Nominal capacity can be defined as the optimal capacity for a particular interconnector.

The actual interconnector capacity, that is the achievable transfers at any point in time, may therefore differ from the nominal.

Care must be taken when reading the values in the tables in this document as the nominal capacity can be affected by adjacent transmission capability, peak loads, nearby generator outputs and availability of load or generation for control schemes. The issues affecting nominal capacity are detailed in the text following the table of nominal capacity.

1.1 Other AEMO publications

For actual interconnector capacity under system normal or outage conditions, AEMO also publishes information in:

- The MMS Data Model[1]. For each interconnector, the current values and constraint equations setting the limit are indicated in the *DispatchInterconnectorRes* table.
- The Monthly Constraint Report[2]. This report summarises the top ten constraint equations that set interconnector limits for the month.
- The Annual NEM Constraint Report[3]. This report analyses interconnector flow and binding level patterns for the calendar year

Together with the above references, this document satisfies the reporting requirements for National Electricity Rule clause 3.13.3(p).

[1] Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/IT-systems-and-change.
[2] AEMO. *Monthly Constraint Report*. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Congestion-information/Statistical-Reporting-Streams. Viewed on: 10 Jan 2017.
[3] AEMO, *Annual NEM Constraint Report.* Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Congestion-information/Statistical-Reporting-Streams. Viewed on: 10 Jan 2017.

2. INTERCONNECTOR CAPABILITIES

2.1 Terranora Interconnector (N-Q-MNSP1)

The Terranora Interconnector is defined as the flow across the two 110 kV lines from Mudgeeraba in Queensland to Terranora in New South Wales.

Terranora is connected to the rest of the electricity network in New South Wales via the direct current (DC) link known as Directlink. This was commissioned in 2000 and formed the first transmission connection between New South Wales and Queensland. Directlink has three pairs of bipolar DC transmission cables. Each pair has a 60 MW maximum capacity, giving Directlink a total rating of 180 MW. Due to local load connected around Terranora, the nominal capacity of Terranora differs from that of Directlink shown in the table below.

Table 1 Terranora Interconnector nominal capacity

From	To	Nominal Capacity
NSW	Queensland	107 MW
Queensland	NSW	210 MW

The Terranora Interconnector is usually constrained by thermal limits in northern New South Wales (such as constraint equation N>N-NIL_LSDU) or the maximum rate of change on Directlink (NQTE_ROC and QNTE_ROC).

2.2 Queensland to New South Wales Interconnector

The Queensland to New South Wales Interconnector (QNI) is defined as the flows across the two 330 kV lines between Dumaresq in New South Wales and Bulli Creek in Queensland. The alternating current (AC) interconnection between New South Wales and Queensland was commissioned in 2001 and consisted of:

- A new double-circuit 330 kV line between Armidale, Dumaresq, Bulli Creek and Braemar.
- A new double-circuit 275 kV line between Braemar and Tarong.
- Two 330/275 kV transformers at Braemar.

Since 2001, a number of generators (Millmerran, Braemar gas turbines and Kogan Creek) and transmission lines have been commissioned in south-west Queensland and connected to these new 275 or 330 kV lines.

Table 2 QNI nominal capacity

From	To	Nominal Capacity
NSW	Queensland	300-600 MW
Queensland	NSW	1078 MW

The transfer from New South Wales to Queensland is mainly limited by the system normal constraint equations for:

- Voltage collapse on loss of the largest Queensland unit (N^^Q_NIL_B1, 2, 3, 4, 5, 6 & N^Q_NIL_B).
- Voltage collapse for trip of the Liddell to Muswellbrook (83) 330 kV line (N^Q_NIL_A).

These transfers are typically limited to between 200 and 400 MW with Kogan Creek in service and can reach up to 600 MW with Kogan Creek out of service and other large Queensland generators at lower output.

Transfer from Queensland to New South Wales is mainly limited by the transient stability limits for fault on either a Bulli Creek to Dumaresq or an Armidale to Dumaresq line (Q:N_NIL_AR_2L-G). This is approximately 1050-1078 MW.

Before July 2013, transfers could be limited by the oscillatory stability limit of 1,078 MW (Q:N_NIL_OSC). On 25 July 2013, this oscillatory stability limit was increased to 1,200 MW so it no longer limits transfers. The limit relies

on the availability of Phasorpoint equipment. (This software determines if there is oscillatory stability in real time.) When Phasorpoint is out of service, the oscillatory stability limit is reduced to 1078 MW.

2.2.1 Previous investigations

TransGrid and Powerlink have previously investigated potential upgrades to QNI. The most recent investigation report was published in November 2014. The regulatory investment tests for transmission (RIT-T) cost-benefit analysis did not identify a preferred credible option. Consequently, TransGrid and Powerlink did not pursue any options to upgrade QNI[4].

2.3 Victoria to New South Wales (VIC1-NSW1)

The Victoria to New South Wales interconnector is defined as the flow across:

- The 330 kV line between Murray and Upper Tumut (65).
- The 330 kV line between Murray and Lower Tumut (66).
- The 330 kV line between Jindera and Wodonga (060).
- The 220 kV line between Buronga and Red Cliffs (0X1).
- The 132 kV bus tie at Guthega (which is normally open).

This interconnector came into operation on 1 July 2008 as part of the Snowy region abolition and replaced the previous “SNOWY1” and “V-SN” interconnectors.[5] The interconnection between NSW and Victoria was commissioned at the same time as the Snowy Hydro scheme. The Wodonga and Buronga lines were added later as a part of strengthening the electricity supply to western NSW and north-west Victoria.

Table 3 VIC1-NSW1 nominal capacity

From	To	Nominal Capacity
Victoria	NSW	700 to 1600 MW
NSW	Victoria	400 to 1350 MW

The nominal capacity of VIC1-NSW1 is highly dependent on the output of Murray generators (for New South Wales to Victoria) and Lower/Upper Tumut generators (for Victoria to New South Wales). VIC1–NSW1 can bind in either direction for high demand in New South Wales or Victoria.

Transfer from Victoria to New South Wales is mainly limited by:

- Thermal overload limits on:
    - South Morang F2 transformer (V>>V_NIL_2A_R, V>>V_NIL_2B_R & V>>V_NIL_2_P).
    - South Morang to Dederang 330 kV line (V>>V_NIL1A_R).
    - Ballarat to Bendigo 220 kV line (V>>SML_NIL_8).
    - Dederang to Mount Beauty 220 kV line (V>>V_NIL_5).
    - Ballarat to Moorabool No.1 220 kV line (V>>SML_NIL_1).
- Transient stability limit for a fault and trip of a Hazelwood to South Morang line (V::N_NILxxx).

Transfer from New South Wales to Victoria is mainly limited by:

- Voltage collapse for loss of the largest Victorian generator or Basslink (N^^V_NIL_1).
- Thermal overload limits on the Murray to Dederang 330 kV lines (V>>V_NIL_1A & V>>V_NIL_1B).

[4] Powerlink. *QNI Upgrade Study*. Available at: http://www.powerlink.com.au/Network/Network_Planning_and_Development/QNI_upgrade_study.aspx. Viewed on: 10 April 2015.

[5] The present Victoria to New South Wales interconnector is equal to the previous V-SN interconnector, plus or minus the output of Murray Power Station, for northwards or southwards flow respectively.

2.4 Basslink (T-V-MNSP1)

Basslink is defined as the flow across the DC cable between George Town in Tasmania and Loy Yang in Victoria. It was commissioned in early 2006 after Tasmania joined the NEM. The commissioning included the undersea DC cable, converter stations and several control schemes in Tasmania. Unlike the other DC lines in the NEM, Basslink has a frequency controller and is able to transfer frequency control ancillary services (FCAS) between Victoria and Tasmania.

Table 4 Basslink nominal capacity

From	To	Nominal Capacity
Tasmania	Victoria	594 MW
Victoria	Tasmania	478 MW

Most of the limitations on Basslink transfers (in both directions of flow) are due to FCAS constraint equations for both mainland and Tasmanian contingency events. The capacity values in Table 4 can be reduced when there is reduced load or generation available for tripping via the frequency control special protection scheme (FCSPS) in Tasmania (T_V_NIL_FCSPS, V_T_NIL_FCSPS).

Basslink has a maximum capability for flows from Tasmania to Victoria transfers is 594 MW (measured at the Loy Yang end). Transfers are mainly limited by the energy constraint equations for the South Morang F2 transformer overload (V>>V_NIL_2A_R, V>>V_NIL_2B_R & V>>V_NIL_2_P) or the transient over-voltage at George Town (T^V_NIL_BL_6).

The maximum capability of Basslink for flows from Victoria to Tasmania is 478MW (measured at George Town). Transfers are mainly limited by the transient stability limit for a fault and trip of a Hazelwood to South Morang line (V::N_NILxxx).

2.5 Heywood Interconnector (V-SA)

The Victoria to South Australia interconnector (Heywood Interconnector) is defined as the flow across the 275 kV lines between Heywood substation in Victoria and South East substation in South Australia (SA). This interconnector was originally commissioned in 1989 as a connection from the western 500 kV network in Victoria (at Heywood near the Portland smelters) to the nearest 275 kV substation at Para, South Australia. It includes a number of connections to the parallel 132 kV network in south-eastern South Australia.

In 2015/16 the Heywood Interconnector was upgraded[6] to include a third transformer at Heywood, series capacitors at Black Range and de-energising 132 kV lines between Snuggery, Keith and Tailem Bend. The nominal design limit is up to 650 MW in either direction of flow. To realise this capacity, AEMO must complete a testing program to verify stability limits. Testing has been completed to verify stability under certain conditions for 600 MW flow from Victoria to SA and 500 MW flow from SA to Victoria. The testing limits[7] remain in place due to:

- Victoria to SA – following the SA black system[8] and identification of potential stability issues above 600 MW, AEMO and ElectraNet are working on reviewing the transfer limits.
- SA to Victoria depends on certain operating conditions and completion of the test program.

Table 5 Heywood Interconnector nominal capacity

From	To	Nominal Capacity
Victoria	South Australia	600 MW
South Australia	Victoria	500 MW

[6] AEMO, *Heywood Interconnector RIT-T*. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Regulatory-investment-tests-for-transmission. Viewed on: 12 Jan 2017.
[7] AEMO. Update inter-network testing and transfer limit – Heywood interconnector. Available at: http://www.aemo.com.au/Market-Notices?currentFilter=&sortOrder=&searchString=56893.
[8] AEMO. *Black System South Australia – Final Integrated Report*. Available at: http://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf. Viewed: 17 May 2017.

The maximum transfer on Heywood from Victoria to South Australia is 600 MW. This is the current testing limit. Transfers can be limited lower than this due to:

- Transient stability for loss of the largest South Australian generator (V::S_NIL_MAXG_xxx) or loss of a South East to Tailem Bend 275 kV line (V::S_NIL_TBSE_xxx).
- Limiting rate of change of frequency to 3 Hz/second for loss of both Heywood to South East 275 kV lines (V_S_NIL_ROCOF).
- Transient stability for fault and trip of a Hazelwood to South Morang 500 kV line (V::N_NILxxx).

South Australia to Victoria transfers on Heywood have an upper limit of 500 MW (current testing limit). Lower transfer levels are due to:

- Thermal overloads on the South Morang F2 transformer (V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P).

The combined Heywood and Murraylink limit from South Australia to Victoria was increased to 580 MW in January 2011. This limit is based on oscillatory stability and relies on the availability of Phasorpoint equipment, which monitors power system oscillatory stability in real time. When Phasorpoint is out of service, the total transfer on both interconnectors is limited to 420 MW.

2.5.1 Historical limitations

Before 2015, the maximum transfer on Heywood from Victoria to South Australia was 460 MW, this was due to the thermal rating on a Heywood 500/275 kV transformer. Transfers could be limited to lower values due to:

- Thermal overloads on the Snuggery to Keith 132 kV line.
- Voltage collapse limit for loss of the largest South Australian generator.

In March 2010, the limit from South Australia to Victoria on Heywood was increased from 300 MW (an oscillatory stability limit) to 460 MW. The 460 MW limit is due to the thermal rating on a Heywood 500/275 kV transformer (S>V_NIL_HYTX_HYTX).

2.6 Murraylink (V-S-MNSP1)

Murraylink is defined as the flow across the DC cable between Red Cliffs in Victoria and Monash in South Australia. It is a 220 MW DC cable that was commissioned in 2002. Runback schemes in South Australia and Victoria were commissioned along with Murraylink, and these handle many of the thermal issues in the Riverland of South Australia and western Victorian 220 kV.

Table 6 Murraylink nominal capacity

From	To	Nominal Capacity at the receiving end
Victoria	South Australia	220 MW
South Australia	Victoria	200 MW

Transfers from Victoria to South Australia on Murraylink are mainly limited by:

- Thermal overloads on:
    - South Morang F2 transformer (V>>V_NIL_2A_R, V>>V_NIL_2B_R & V>>V_NIL_2_P).
    - South Morang to Dederang 330 kV line (V>>V_NIL1A_R).
    - Ballarat to Bendigo 220 kV line (V>>SML_NIL_8).
    - Dederang to Mount Beauty 220 kV line (V>>V_NIL_5).

- Voltage collapse for loss of the Darlington Point to Buronga (X5) 220 kV line for an outage of the NSW Murraylink runback scheme (V^SML_NSWRB_2[9]).

South Australia to Victoria transfers on Murraylink are normally limited by thermal overloads on:

- Robertstown to Monash 132 kV lines (S>V_NIL_NIL_RBNW).
- Dederang to Murray 330 kV lines (V>>V_NIL_1A & V>>V_NIL_1B).

2.6.1 Proposed Augmentations

ElectraNet has planned a staged upgrade to the Robertstown to North West Bend 132 kV line. It is anticipated that this will reduce the binding hours for constraint equation S>V_NIL_NIL_RBNW. The upgrades include:

- Increase thermal capacities of Robertstown to North West Bend No. 2 and North West Bend to Monash No. 2 132 kV lines. This is part of ElectraNet's Network Capability Incentive Parameter Action Plan[10] approved by the AER in May 2015. The work is scheduled for the year 2016-17.
- In addition to the thermal upgrade, ElectraNet is looking to introduce dynamic line rating of both Robertstown to North West Bend 132 kV lines. This may at times increase the interconnector capability.

Murraylink has proposed[11], as a part of their five-year revenue reset, to implement the NSW Murraylink Runback scheme. This should relieve the constraint equation V^SML_NSWRB_2. Implementation is likely in summer 2017/18.

[9] The NSW Murraylink runback scheme has not yet been commissioned so this constraint equation is currently part of the Victorian system normal constraint set. See further Section 2.6.1.

[10] ElectraNet SA, *Network Capability Incentive Parameter Action Plan*, Available at: https://www.electranet.com.au/wp-content/uploads/resource/2016/06/20150327-Report-NetworkCapabilityIncentiveParameterActionPlan.pdf. Viewed on 12 Jan 2017.

[11] Murraylink, *Murraylink revised revenue proposal 2013 - Business cases*, Available at: https://www.aer.gov.au/system/files/Murraylink%20revised%20revenue%20proposal%202013%20-%20Business%20cases.pdf. Viewed on 12 Jan 2017.

MEASURES AND ABBREVIATIONS

Units of measure

Abbreviation	Unit of measure
kV	A kilovolt is one thousand volts, and is used to define the voltage of transmission lines.
MW	A megawatt 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.

Abbreviations

Abbreviation	Expanded name
AC	Alternating Current
AEMO	Australian Energy Market Operator
Constraint equation	These are the mathematical representations that AEMO uses to model power system limitations and FCAS requirements in the National Electricity Market Dispatch Engine (NEMDE).
DC	Direct Current
FCAS	Frequency Control Ancillary Services
NEM	National Electricity Market
Phasorpoint	Application that analyses the PMU data to monitor oscillatory stability in real-time.
PMU	Phasor measurement unit. (Used by AEMO to monitor the oscillatory stability in the NEM.)
RIT-T	Regulatory investments tests for transmission.
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.