ASSESSMENT OF INTER-REGIONAL CONGESTION

Report to the AEMC

3 November 2011

Final Report

Intelligent Energy Systems

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Executive Summary

Introduction

Intelligent Energy Systems (IES) was contracted by the Australian Energy Markets Commission (AEMC) to identify any apparent planning shortfall regarding inter-regional transmission which might warrant the exercise of the Last Resort Planning Power (LRPP) under the National Electricity Rules. This was done by reviewing the NTNDP and NTS documents produced by AEMO and comparing any congestion issues or inter-regional transfer upgrades identified in these reports with upgrade opportunities discussed in the TNSP Annual Planning Reports (APRs).

Report Outline

This report consists of the following components:

- A brief overview of congestion in the NEM;
- A discussion of constraints and their influence on interconnector flows in the NEM including a worked example of the Mt Piper – Wallerawang constraint;
- A summary of the 2010 NTNDP and 2009 NTS published by AEMO with respect to the inter-regional planning opportunities noted in these reports;
- An analytical review of the TNSP Annual Planning Reports (APRs) and any other relevant TNSP documentation, focusing on the planning initiatives related to inter-regional network development; and
- The identification of any "gaps" where a TNSP has not responded adequately to planning opportunities identified by AEMO in its NTNDP and NTS, and if so, a recommendation as to whether there is any need for the AEMC to undertake further analysis.

Conclusions

IES compared the TNSP's Annual Planning Reports (APRs) with opportunities that AEMO has identified for upgrading inter-regional transfer capabilities in the NTNDP to check there were any forecasts of congestion or upgrade opportunities that AEMO had identified which were not being pursued.

The AEMO NTNDP stated that a transfer capability upgrade between the SWQ and NNS zones (via QNI) would be likely to deliver net market benefits. On this basis, AEMO recommended early attention be given to an upgrade of the QNI interconnector. In response to this, Powerlink and TransGrid have commenced an investigation of the economic viability and optimum timing of various upgrade options to the QNI interconnector based on the methodology of the RIT-T. This report is due to be released in the second half of 2011.

Also, the AEMO NTNDP indicated that upgrades of the other interconnectors are not required at present time, although preparatory work would be advised in some cases. TransGrid, AEMO (as JPB for Victoria) and ElectraNet all reported in their respective APRs that they will be undertaking investigations of their networks with a view to monitoring and assessing future potential upgrades of the inter-regional flow paths.

IES advises that in our opinion, all the high level projects related to inter-regional transmission planning raised by the AEMO NTNDP appear to be being addressed by the relevant jurisdictional planning bodies. Consequently, IES considers that there is no indication of any planning shortfall regarding inter-regional transmission which might require the exercise of the Last Resort Planning Power (LRPP). Accordingly, IES recommends that no further analysis is required.

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Glossary

Term	Definition
ACCC	Australian Competition and Consumer Commission
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ANTS	Annual National Transmission Statement
APR	Annual Planning Report
CMC	Cumulative Marginal Cost
DNSP	Distribution Network Service Provider
ESOO	Electricity Statement of Opportunities
FCAS	Frequency Control Ancillary Service
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IES	Intelligent Energy Systems
JPB	Jurisdiction Planning Body
LRPP	Last Resort Planning Power
MNSP	Market Network Service Provider
NCSPS	Network Control System Protection Scheme
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine
NER	National Electricity Rules
NTFP	National Transmission Flow Path
NTNDP	National Transmission Network Development Plan
NTS	National Transmission Statement
QNI	Queensland – New South Wales Interconnector
RIT-T	Regulatory Investment Test – Transmission
TNSP	Transmission Network Service Provider

1 Introduction

Intelligent Energy Systems (IES) has been contracted by the Australian Energy Market Commission (AEMC) to undertake an assessment of inter-regional congestion. The primary objective of the consultancy is to determine whether any apparent planning shortfall exists regarding inter-regional transmission which might warrant the exercise of the Last Resort Planning Power (LRPP) under the National Electricity Rules.

1.1 Background and Scope of Work

The last resort planning power (LRPP) is an oversight mechanism which allows the AEMC to direct parties to apply the RIT-T to specific projects. It is intended to ensure that there is efficient inter-regional transmission investment across the NEM.

The AEMC is required to report annually on the matters it has considered, in deciding whether or not to exercise the LRPP in that year. The AEMC has contracted IES to provide a brief report comparing AEMO planning proposals as expressed in the National Transmission Network Development Plan (NTNDP) and National Transmission Statement (NTS) against Transmission Network Service Provider (TNSP) responses to these documents.

The purpose of the comparative report is to identify any apparent planning shortfall regarding inter-regional transmission which might warrant the exercise of the LRPP under the National Electricity Rules. The report is to include the following components:

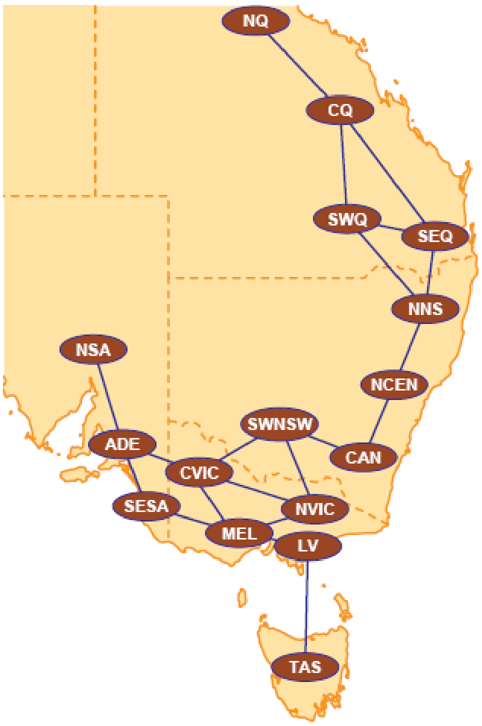
- A brief overview of congestion in the NEM;
- A discussion of constraints and their influence on interconnector flows in the NEM including an example (Mt Piper/Wallerawang constraint suggested);
- A summary of the 2010 NTNDP and 2009 NTS published by AEMO with respect to the inter-regional planning opportunities noted in these reports;
- An analytical review of the TNSP Annual Planning Reports (APRs) and any other relevant TNSP documentation, focusing on the planning initiatives related to inter-regional network development; and
- The identification of any "gaps" where a TNSP has not responded adequately to planning opportunities identified by AEMO in its NTNDP and NTS, and if so, a recommendation as to whether there is any need for the AEMC to undertake further analysis.

2 Background

2.1 Interconnectors in the National Electricity Market

The National Electricity Market (NEM) operates as a wholesale electricity market in the eastern and southern states of Australia. The NEM is divided into five regions which roughly follow the state boundaries: Queensland, New South Wales (including the Australian Capital Territory), Victoria, South Australia and Tasmania. For planning purposes the NEM is further broken up into sixteen national transmission zones, shown in Figure 2-1. These transmission zones are used for transmission planning and a range of modelling studies.

Figure 2-1 National Transmission Zones in the NEM



Key:	
National Transmission Zone	**Abbreviation**
North Queensland	NQ
Central Queensland	CQ
South West Queensland	SWQ
South East Queensland	SEQ
North New South Wales	NNS
Central New South Wales	NCEN
Canberra	CAN
South West New South Wales	SWNSW
Northern Victoria	NVIC
Country Victoria	CVIC
Melbourne	MEL
Latrobe Valley	LV
Northern South Australia	NSA
Adelaide	ADE
South East South Australia	SESA
Tasmania	TAS

Source: Tasmania Annual Planning Report 2011, Transend

Six interconnectors (high voltage transmissions lines) transport electricity between adjacent NEM regions. Table 2-1 lists the interconnectors along with their regions, flow path and name.

Table 2-1 NEM interconnectors

Region	Name	Flow path
New South Wales – Queensland	QNI	NNS – SWQ
New South Wales – Queensland	Terranora (formerly Directlink)	NNS – SEQ
Victoria – New South Wales	Vic – NSW	NVIC – SWNSW, CVIC – SWNSW
Victoria – South Australia	Heywood	MEL – SESA
Victoria – South Australia	Murraylink	CVIC – ADE
Tasmania – Victoria	Basslink[1]	LV – TAS

Note that the QNI, Vic-NSW and Heywood interconnectors are HVAC links while Terranora, Murraylink and Basslink are HVDC links.

2.2 Congestion in the Transmission Network

A transmission line is congested when the power flows along the line are constrained to levels less than desired. Congestion generally results in the dispatch of more expensive generation than otherwise would have been the case and very occasionally, curtailment of loads.

Power system security in the NEM is managed by controlling the output of dispatchable resources such as generators, dispatchable loads and DC transmission lines so that the power system remains in a secure state. Principally this involves ensuring that the power system remains within its technical limits. These limits may correspond to the maximum flows on one or more power lines such that pre-contingent flows will be maintained below the continuous ratings of the relevant network elements and post-contingent flows will be maintained below the emergency ratings of the relevant equipment. These limits are called thermal limits. Other limits may correspond to managing transient stability, steady state stability or voltage stability. In these cases the maximum power flows are not directly related to managing the ratings of network equipment but to other aspects of the power system.

The limits on power flows can be influenced by events occurring far away from the physical line that is constrained. For instance, in 2007/08, the Heywood interconnector was constrained in the Victoria to South Australia direction for 181 hours when the Northern Power Station located at Port Augusta lost a generating unit due to a two-phase to earth fault near the station.[2]

[1] Note that Basslink is the only unregulated interconnector. A regulated interconnector has been examined under an ACCC-devised regulatory test and deemed to add net market value to the NEM. It then receives a fixed annual revenue based on its asset value regardless of usage. In contrast, an unregulated (market) interconnector derives its revenue from the purchase and sale of the electricity it carries.
[2] Page 10-6, 2008 ANTS, AEMO.

2.3 Transmission and Regulatory Bodies

A number of government and corporate bodies are involved in the regulation, operation and functioning of the transmission network in the National Electricity Market. The main ones are detailed below:

- Australian Energy Regulator (AER) – regulator of the wholesale electricity and gas markets including transmission and distribution in all jurisdictions other than Western Australia;
- Australian Energy Market Commissions (AEMC) – a national, independent body responsible for making and amending the rules for the NEM and some aspects of Australia's gas markets;
- Australian Energy Market Operator (AEMO) – industry body who operates the NEM (power system and electricity market) as well as the retail and wholesale gas markets in south eastern Australia under the rules set by the AEMC;
- Jurisdictional Planning Bodies (JPBs) – bodies responsible for planning a jurisdiction's electricity transmission network. JPBs for the NEM are:
  - TransGrid (New South Wales);
  - Powerlink Queensland (Queensland);
  - ElectraNet (South Australia)[3];
  - Transend Networks (Tasmania); and
  - AEMO (Victoria)[4].
- Transmission Network Service Providers (TNSPs) - the owners, operators or controllers of a high voltage electricity transmission network. In a majority of cases, the TNSPs also serve as the JPB in its jurisdiction. TNSPs in the NEM[5] include:
  - TransGrid (New South Wales)
  - Powerlink Queensland (Queensland);
  - ElectraNet (South Australia);
  - Transend Networks (Tasmania);
  - SPI PowerNet[6] (Victoria);
  - Directlink;
  - Murraylink Transmission Company;
- Market Network Service Providers (MNSPs) - the owners, operators or controllers of an unregulated (market) high voltage electricity transmission network[7]. Currently the only MNSP in the NEM is Basslink.

[3] Prior to its incorporation into AEMO on 1 July 2009, the Electricity Supply Industry Planning Council (ESIPC) acted as JPB for South Australia.
[4] Prior to its incorporation into AEMO on 1 July 2009, the Victorian Energy Networks Corporation (VENCorp) acted as JPB for Victoria.
[5] As stated in the list of NEM Market Participants published by AEMO last updated 31 May 2011.
[6] SPI PowerNet is the licensed transmission entity of SP AusNet
[7] Unregulated (or market) interconnectors derive revenue by purchasing energy in a lower priced region and selling it to a higher priced region, or by selling the rights to revenue traded across the interconnector. Unregulated interconnectors are not required to undergo the regulatory test evaluation.

3 Transmission System and Dispatch Process

In order to understand how the transmission system is managed in the NEM and how congestion on interconnectors may occur, it is worthwhile discussing how transmission limits are managed in the NEM's dispatch optimisation and how limitations in parts of the NEM's meshed network distant from regional boundaries may affect inter-regional flows.

3.1 NEM Network Model

The NEM market design is a regional model with 5 regions and 6 interconnectors (5 nodes and 6 lines / branches), whereas the physical network is an AC meshed network, with some DC elements. The physical network has over 2,000 nodes (connection points and busses) and around 3,000 lines / branches. The physical network is much more complicated than the market model.

Unlike some markets which have explicit dispatch models of the underlying physical transmission system, the NEM has a regional energy pricing structure and an implicit network model.

The dispatch engine explicitly models generator, load, MNSP and notional interconnector dispatches. Network and power system security issues are managed by the implicit network model in the NEM dispatch engine (NEMDE). This is done via the use of "generic constraints" which limit generator dispatches and interconnector flows in order to maintain the power system in a secure state.

The NEM interconnectors are notional interconnectors and are effectively made up of a large number of physical network elements. Congestion in any one of these physical network elements can cause congestion in an interconnector. Over the last 3 years over 3,000 interconnector constraints have bound[8].

3.2 NEM Dispatch Engine (NEMDE)

NEMDE is a linear programming (LP) optimisation that minimises the dispatch costs based on participant bids (loads) and offers (generators) for energy and frequency control ancillary services (FCAS), subject to meeting the regional demands and satisfying network and security constraints. NEMDE runs every five minutes and produces as outputs:

- the dispatches of energy and FCAS for generators and dispatchable loads;
- interconnector flows and losses;
- as list of the network and security constraints that have bound and hence constrained the market dispatch of energy, FCAS and interconnector flows;
- regional energy prices; and
- shadow prices or marginal costs of constraints.

[8] A constraint is binding if the constraint affects the dispatch. A constraint is said to be binding in a linear program (optimisation) if a small perturbation of its right hand side (RHS) changes the value of the objective function (the function the linear program is trying to optimise).

3.3 Constraint Equations

As mentioned above, NEMDE dispatches generation within the thermal, voltage, and stability limits of the transmission network. These limits are managed by constraint equations in the dispatch process. Terms which occur in constraint equations represent physical attributes such as generation output from power stations, thermal limits of transmission lines, electricity demand in various locations, flows in the network and availability of reactor and capacitor banks.

Each constraint equation or set of constraint equations represents a particular type of power system limitation or requirement. Constraint equations can also exist for specific configurations of the power system such as system normal or plant outages. These power system limitations include the following types[9].

Network:

- Thermal – for managing the power flow on a transmission element so that it does not exceed a rating (either continuous or short term) under normal conditions or following a credible contingency;
- Voltage Stability – for managing transmission voltages so that they remain at acceptable levels after a credible contingency;
- Transient Stability – for managing network flows to ensure the continued synchronism of all generators on the power system following a credible contingency;
- Oscillatory Stability – for managing network flows to ensure the damping of power system oscillations is adequate following a credible contingency; and
- Network Control Schemes – the modelling of generator control schemes or reactive control devices on generator output.

Frequency Standards: maintain the frequency within the Reliability Panel standards by dispatching Frequency Control Ancillary Services ;

Other:

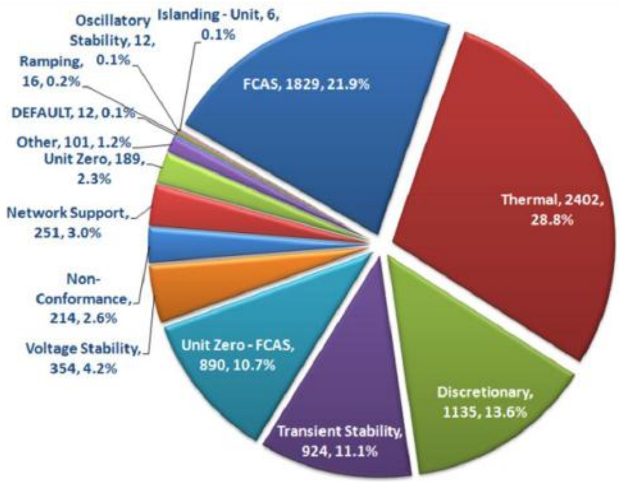
- Managing Negative Residues;
- Rate of Change (Interconnectors and Generators);
- Non-Conformance;
- Network Support Agreement;
- Unit Zero; and
- Discretionary limit on generators and/or interconnectors.

Currently there are around 8,900 constraint equations used to manage generation and electricity transmission in the NEM[10]. Figure 3-1 shows a breakdown of the constraint equations by the type of limit they manage.

[9] Source: AEMO, "Constraint Formulation Guidelines", Document Ref: 170-0040, Version: 10, 6 July 2010
[10] Excluding archived constraint equations or those pertaining to outage ramping. Page 6, The Constraint Report 2010, AEMO

Congestion in the network may be identified by observing which constraint equations are binding or violating. Importantly, the amount of time that a constraint equation is binding only provides information regarding how long generator outputs or flows on one or more interconnectors have been constrained. It does not provide any measure of the economic costs of this congestion. The marginal cost of a binding constraint provides some information regarding the cost of a constraint to the market.

Figure 3-1 Breakdown of constraint equations by limit type



Source: The Constraint Report 2010, AEMO

3.4 Inter-regional Constraints

In assessing the impact of constraints on inter-regional congestion an immediate issue is the definition of an inter-regional constraint. Inter-regional constraints are often perceived to occur only at the physical boundary between regions. This definition overlooks the realities of the physical transmission network. Owing to the meshed nature of the transmission system the flow between two regional reference nodes can be limited by sections of the physical network distant from the regional boundary. Basically any line in the meshed part of the network between regions can affect the inter-regional flows between the regions.

For a physical transmission line that can affect generator and inter-regional flows there will correspond one or more network constraints in the dispatch process that are used to manage the flows on this line. Thus we define an inter-regional constraint to be one that contains an interconnector term in the constraint equation[11]. In simple terms, an inter-regional constraint is one that can affect the dispatch of flow between two regional reference nodes. An example of an inter-regional constraint that is distant from any regional boundary is the constraint

[11] A generic constraint is classified as an inter-regional constraint if it includes an interconnector flow term in the constraint's left hand side (LHS). That is, the constraint has a non-zero coefficient for one or more interconnector flow terms in its left hand side.

"N>>N-NIL__S" which is a system normal constraint associated with the 70 and 71 lines between Mt Piper and Wallerawang in New South Wales.

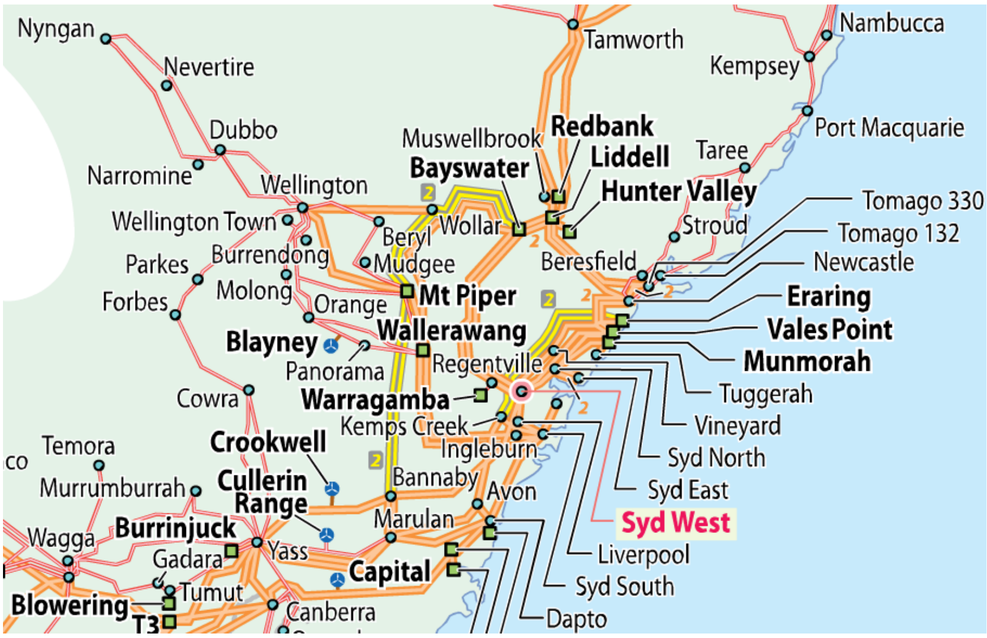
3.4.1 Example: Mt Piper to Wallerawang

The 70 and 71 lines between Mt Piper and Wallerawang in New South Wales are shown Figure 3-2 and Figure 3-3. These diagrams show the physical transmission network in the area surrounding these lines.

Figure 3-2 Schematic of transmission network in NSW

Source: AEMO

Figure 3-3 Transmission network map of Sydney area in NSW



Source: AEMO

The constraint N>>N-NIL__S is used to avoid an overload on the Mt Piper to Wallerawang line (line 70) on a trip of the Mt Piper to Wallerawang line (line 71). This is a system normal constraint with feedback which is used to manage a thermal limit.

Notwithstanding the location of the power lines involved, the terms in the left hand side of this constraint equation include inter-regional flows across the Vic-NSW, QNI and Terranora interconnectors as well as southern and western New South Wales generation (Uranquinty, Mt Piper, Redbank, Liddell, Bayswater and Snowy generation located in New South Wales). Thus, when binding, the constraint N>>N-NIL__S has an impact upon both New South Wales generation and three interconnectors: QNI, Terranora, and Vic-NSW.

The 2010 NTNDP lists the N>>N-NIL__S constraint as being one of the network constraint equations which bound more than 100 hours in the 2009/10 year[12]. During this period, it impacted on southerly flow on the QNI and Terranora interconnectors as well as northerly flow on the Vic-NSW interconnector[13].

3.4.2 Relative number of inter-regional constraints

IES has examined the Market Management System (MMS) database of constraints to determine the proportion of constraints that are inter-regional (i.e. contain an interconnector term). Table 3-1 shows the relative proportion of inter-

[12] Table D.2, 2010 NTNDP, AEMO

[13] According to the 2010 AEMO Constraint Report, this constraint equation bound heavily in late 2009 and early 2010 due to the outage of a Wallerawang unit. AEMO and TransGrid agreed to an operational arrangement to reduce the time this constraint equation bound. In August 2010 TransGrid completed changes which increased the rating to the point where this constraint equation would bind rarely (if at all) into the future.

regional constraints. The total set of constraints includes both system normal and outage constraints. Excluded from this table are a number of constraints associated with outage ramping, constraint automation, and constraints that have been archived such as those associated with the now abolished Snowy Region.[14]

Table 3-1 Inter-regional constraints as a proportion of total constraints

Constraint Type	Total Inter-regional constraints	Total Constraints	Inter-regional constraints as proportion of total
FCAS	657	1,821	36%
Network (All limit types other than FCAS)	5,563	8,302	67%
TOTAL	**6,220**	**10,123**	**61%**

Source: Extracted from MMS database.

There are around 5,500 inter-regional network constraints. Interconnector flows are influenced not by a handful of constraints associated with "pinch-points" at regional boundaries, but are a function of numerous limitations across the majority of the physical network. Excluding FCAS constraints, around 67% of constraints are inter-regional.

[14] The figures presented in this table may include some constraints that have been archived and are no longer in use. This information is not readily available from the MMS database.

4 Assessment of Planning Documents

IES reviewed a number of documents in order to determine whether the planning processes currently in place were adequately addressing any significant interregional congestion. The documents we reviewed were:

- the 2009 National Transmission Statement (NTS);
- the 2010 National Transmission Network Development Plan (NTNDP);
- Annual Planning Reports (APRs); and
- other AEMO and TNSP reports related to interconnector augmentations.

A summary of the key findings of these reports is presented in this section.

4.1 AEMO National Transmission reports

The AEMO NTS and AEMO NTNDP documents report on transmission planning with a high-level medium to long term view. In contrast, the AEMO Constraint Report and the Annual Planning Reports published by the various JPBs take a more detailed and shorter-term view of congestion and transmission planning.

4.1.1 2009 National Transmission Statement (NTS)

The 2009 NTS was a transitional document that replaces the Annual National Transmission Statement (ANTS). In it, AEMO reported that power flows were unconstrained for the majority of the time on all interconnectors other than Basslink during the 2008-09 year. Power flows on Basslink were limited almost all of the time, primarily by constraints associated with the Tasmanian Frequency Control Special Protection Scheme (FCSPS)[15].

The ten most frequently binding system normal constraints impacting on interconnector flows were identified. Of these, five were the subject of an ongoing investigation or upgrade. The other five were all incorporated into conceptual augmentations (potential augmentations involving one or more network elements) tested in the 2009 NTS. The market costs of these constraints were not stated.

Fifty-one conceptual augmentations that would be expected to significantly impact national transmission flow path capability were identified by AEMO and the TNSPs. Six of these were considered for further examination and two conceptual augmentations were finally selected to be tested in the NTS market simulations[16]:

- Case 1 – QNI series compensation (which had also been found to have positive net market benefits in the 2008 ANTS); and

[15] These constraint equations limit power flow over Basslink to maintain system frequency within acceptable levels following a trip of Basslink.
[16] Appendix E, 2009 National Transmission Statement, AEMO

- Case 2 – QNI series compensation, a Loy Yang braking resistor and a Hunter Valley - Gold Coast 500kV line development.

The NTS concluded that both conceptual augmentations demonstrated positive market benefits in low and high carbon pricing environments, although the benefits for Case 2 were substantially reduced in the high carbon pricing scenario. Finally, it was noted that “the NTS only assessed a limited number of conceptual augmentations, and there may be other network augmentations that deliver sufficient market benefits to justify proceeding. For example, results suggest potential value in an augmentation that relieves congestion between South Australia and Victoria.”

4.1.2 2010 National Transmission Network Development Plan (NTNDP)

The NTNDP provides information on the strategic and long-term development of the national transmission system under a range of market development scenarios. As such it concerns itself with the wider view of transmission development rather than analysing near-term upgrade options in detail.

The NTNDP reports the number of hours each interconnector was constrained and the related constraint equations which were binding more than 100 hours in the 2009-10 year are listed[17]. The market costs of these constraints were not stated.

The 2010 NTNDP incorporates a change in modelling approach from the earlier NTS and ANTS reports regarding transmission development. Future transmission congestion and upgrades were modelled in conjunction with future generation development under ten different scenarios, allowing the potential drivers of upgrade options to be explored.

A summary of the NTNDP results regarding inter-regional flows is given below:

- In five of the scenarios, a transfer capability upgrade between the SWQ and NNS zones (via QNI) was found to deliver net market benefits[18].
- All ten scenarios indicated that the 220kV Balranald-Buronga line becomes congested in the future due to high power exports to South Australia over Murraylink. This was alleviated in the modelling by regulating the power flow between the CVIC and SWNSW zones. A single scenario also suggested more comprehensive upgrades to the Victoria - New South Wales interconnector on the basis of net market benefits by allowing an increased output of black coal generation in New South Wales. Finally, the time-sequential modelling resulted in considerable network congestion in all scenarios caused by potential overload of the 330kV Murray-Upper Tumut line for an outage of the 330kV Murray-Lower Tumut line. However no upgrades to the Vic-NSW interconnector were selected by the high level

[17] Appendix D, 2010 National Transmission Network Development Plan, AEMO
[18] Page 88-89, 2010 National Transmission Network Development Plan, AEMO

least-cost expansion optimiser due to the high estimated costs of these potential upgrades.

- Upgrades of the Heywood interconnector were only selected in two of the ten scenarios, both in the period 2025/26-2029/30. They were driven primarily by extensive new geothermal and wind generation entering in South Australia. The NTNDP also states that a joint feasibility study into transmission development options between South Australia and other NEM load centres was carried out in late 2010 by ElectraNet and AEMO[19]. Further information regarding this study may be found in Section 4.3.2.
- The 2010 NTNDP did not consider any augmentation options for the Victoria - Tasmania flow path.

A list of the interconnector upgrades recommended in the 2010 NTNDP is presented in Table 4-1.

Table 4-1 Summary of interconnector upgrades recommended by the 2010 AEMO NTNDP

Inter-connector	NTNDP recommend-ation	Suggested augmentation	Drivers
QNI	Early attention	Series compensation on Armidale-Dumaresq 330kV circuits and Dumaresq-Bulli Creek 330kV circuits[20]	NSW exporting to QLD during high demand, QLD exporting to NSW during lower demand
Vic-NSW	Preparatory work	Installing a phase shifting transformer (TX) on the 220kV Buronga-Red Cliffs circuit.	High power exports from Vic to SA over Murraylink
Vic-NSW	Preparatory work	Additional transformers at Dederang and South Morang, a phase angle regulator on the Jindera-Wodonga circuit and series capacitors on the Eildon-Thomastown and Wodonga-Dederang circuits. Uprating the Eildon-Thomastown and South Morang-Dederang circuits, and cut-in of the Rowville-Thomastown circuit.[21]	Increased NSW to Vic exports during low demand
Vic-SA	None given	Additional transformers at Heywood and South East substations, a shunt capacitor bank at the South East substation and utilisation of line design ratings for relevant circuits in the SESA zone and Eastern Hills. Previous augmentation for Vic-SA (shown above) as well as series compensation on 275kV Tailem Bend-South East circuit.	Increased renewable generation in SA exporting to Vic during non peak load conditions

The NTNDP also presents a new conceptual project called NEMLink which would enable large scale power transfers between NEM regions. It comprises a high capacity 500kV double circuit backbone connecting the mainland regions within the NEM, and 400kV HVDC link connecting Tasmania and the mainland regions. The project includes a number of intermediate substations, switching stations and devices for reactive compensation and power flow control.

[19] http://www.electranet.com.au/network/transmission-planning/interconnection-studies/
[20] As proposed by the Powerlink in its 2010 APR, Chapter 5, Section 5.2.3.
[21] For more information, see pages 101-102, 2010 NTNDP, AEMO.

4.2 Annual Planning Reports

The primary purpose of the APR's is to provide information on the short-term to medium-term planning activities of TNSPs, whereas the focus of the NTNDP is strategic and longer term. This section reviews the information related to inter-regional transmission provided in the 2011 APRs.

4.2.1 New South Wales Annual Planning Report 2011 – TransGrid

The New South Wales 2011 APR does not provide a review of the performance of the New South Wales transmission system over the recent past, focussing instead on future transmission upgrades in the region.

The APR responds to the two Victoria-New South Wales interconnector upgrades recommended in the NTNDP (summarised in Table 4-1) as follows[22]:

- **NV1:** The NSW 220kV system has a relatively high thermal rating compared to the voltage control capability. The feasibility of a phase shifting transformer (PST) installation is under investigation. TransGrid and AEMO will investigate the impacts of high Murraylink power transfers on the NSW and Victorian systems in the Buronga – Red Cliffs area.
- **NV2:** There are a number of options for upgrading the interconnection and joint work would be undertaken by TransGrid and AEMO.

The current, proposed and long term future augmentations of the New South Wales transmission network listed in the APR identified as impacting on inter-regional flows are shown in Table 4-2, Table 4-3 and Table 4-4.

Table 4-2 NSW – Completed, committed and planned augmentations related to inter-regional flows

Status	Augmentation	Details
Recently completed	Uprating of Tamworth – Armidale 330kV Line No. 86	This provides increased power transfer capability from Tamworth to Armidale and then to Queensland.
Committed	Installation of two 200 MVAr switched shunt capacitor banks at Armidale	Increases the transfer capability between NSW and Qld governed by voltage control limitations.

Source: Chapter 5, New South Wales APR 2011

Table 4-3 NSW – Proposed network developments (within 5 years) related to inter-regional flows

Driver/s	Development
Snowy-Yass/Canberra four 330kV lines often loaded to max capacity during high NSW loads.	Upgrade would provide increased power transfer capability to Yass/Canberra via Lower & Upper Tumut including export from Victoria.
Conflicting Snowy voltage levels required due to NSW-Vic flows and Canberra-Kangaroo Valley flows	Relocate 330kV shunt reactor from Kemps Creek to Yass
Murraylink constrained by power transfer capacity of 220kV system between Darlington Point and	Complete communication links between substation controls installed at various NSW

[22] Page 29, New South Wales Annual Planning Report 2011, TransGrid.

Buronga and the Victorian NW 220kV system	sites and Murraylink[23].

Source: Chapter 6, New South Wales APR 2011

Table 4-4 NSW – Longer term possible transmission constraints and developments related to inter-regional flows

Network	Details
Yass – Banaby and Yass – Marulan 330kV lines	Significant southern NSW generation development coupled with higher levels of import from Victoria could result in power transfer capability being reached.
Hunter Valley – Tamworth – Armidale 330kV system	Sections of the system impose limitations on the capability for NSW export to Qld at times of high northern load.
Tamworth and Armidale 330kV switchyards	Existing switchyards were constructed before QNI was connected to Armidale. Equipment reliability is considered insufficient for this critical part of the network, particularly if new wind farms and gas-fired generation develop in the area as expected.
NSW – Vic interconnection	TransGrid to undertake further work with AEMO regarding phase shifting transformer between Buronga and Red Cliffs as discussed in 2010 NTNDP; TransGrid have also investigated various other options and currently have a long term plan to develop 500kV links from Bannaby – Yass – Wagga with further interconnection development from Wagga to Victoria. This would form part of the NEMLink development as mentioned in the 2010 NTNDP.
NSW – SA interconnection	A direct interconnector between the two regions would allow the import of excess renewable generation from SA to NSW and the transfer of baseload generation from NSW to SA.
QNI	A joint investigation between TransGrid and Powerlink into the potential upgrade of QNI is ongoing. See 4.3.1 for more details.

Source: Chapter 6, New South Wales APR 2011

4.2.2 Queensland Annual Planning Report 2011 – Powerlink

The Queensland APR provides a qualitative summary of the major system conditions affecting transfer capability across key grid sections of the Queensland network. The impact of individual constraints or constraint sets is therefore not included. Historic performance of the Queensland network is presented in terms of the number of hours that each grid section was constrained during the 2010-11 summer and winter periods. Regarding network capability related to inter-regional flow, the APR reports the following[24]:

- Network limitations in supplying the Gold Coast zone (which connects to the Terranora interconnector) are not forecast to emerge within five years; and
- Over the 2010-11 year, the South West Queensland (SWQ) grid section was constrained for a total of 5.41 hours or 0.06% of the year[25]. However, due to load growth in Queensland and the commissioning of new generation in the Bulli zone, transfer limits are forecast to impact supply reliability from summer 2011/12. This issue is presently being addressed by a series of committed projects shown below in Table 4-5.

[23] Murraylink's owners have already undertaken to carry out these works
[24] Section 4.4, Queensland Annual Planning Report 2011, Powerlink
[25] This impacts on inter-regional flow as the SWQ grid section transfers power from generating stations located in the Bulli zone and northerly flow on QNI to the rest of Queensland.

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Table 4-5 QLD – Completed, committed and planned augmentations related to inter-regional flows

Status	Augmentation	Details
Committed	Western Downs – Halys 275kV double circuit line and 275kV substations	Increase SWQ thermal limit by around 800MW
Committed	Millmerran 200MVAr 330kV capacitor bank; Middle Ridge two 120MVAr 330kV capacitor banks	Preserves SWQ limit transfer capability

Source: Appendix F, Queensland APR 2011

The APR notes that a joint investigation between TransGrid and Powerlink into the potential upgrade of QNI is ongoing (see Section 4.3.1 for more details) and lists some potential network projects related to flow on QNI (shown in Table 4-6).

Table 4-6 QLD – Potential projects related to upgrade of QNI[26]

Network project	Indicative cost	Potential impact on network limits
Armidale second 330kV SVC	$50M (approximately)	Increases QNI stability limits by around 150MW in the northerly direction
High speed protection schemes and Loy Yang braking resistor	$35M (approximately)	Increases QNI stability limits by up to 300MW in the southerly direction
Bulli Creek to Dumaresq and Dumaresq to Armidale 330kV thyristor controlled series capacitors (and supporting works)	$125M (10) (approximately)	Increases QNI stability limits by up to 400MW in both directions
Bulli Creek or Dumaresq 1,500MW HVDC back to back asynchronous link	$490M (approximately)	Increases QNI transfer capability by around 500MW in both directions
Bulli Creek to Bayswater 330kV double circuit line (with intermediate switching stations)	$950M (approximately)	Increases QNI transfer capability by around 500MW in the northern direction and around 1,000MW in the southern direction
Western Downs to Bayswater 500kV double circuit line (with intermediate switching stations and dynamic compensation devices)	$2,000M (11) (approximately)	Increases QNI transfer capability by around 1,800MW in both directions

Source: Page 143, Queensland Annual Planning Report 2011, Powerlink

4.2.3 South Australian Annual Planning Report 2010 – ElectraNet

The South Australian APR lists the top twenty network constraints (by total marginal value) in the South Australian network during the 2010 calendar year. Seven of these constraints have been identified as pertaining to inter-regional

[26] Further information regarding these constraints may be found in Appendix 1 of the Powerlink and TransGrid “Final Report: Potential Upgrade of QNI” (13 October 2008) available on either the Powerlink or TransGrid web sites.

flows and are presented in Table 4-7. Of these seven constraints, one has already been alleviated by the uprating of the Waterloo bus. The other six constraints are currently under investigation by ElectraNet.

Table 4-7 SA – Inter-regional constraints which appear among the top 20 network constraints experienced during 2010

Constraint equation	∑marginal value / Hrs constrained	Constraint description	Commentary
V^^S_NIL_NPS_xxx & V^^S_TBCP_NPS_xxx & V::S_NIL	$548,852, 485.33 hrs	Vic to SA long term voltage stability limit for loss of one Northern unit, South East cap bank on/off, Tailem Bend cap bank on / off	Currently under investigation
S>>V_NIL_NIL_MNWT	$241,060, 8.83 hrs	Avoid overload of Mintaro to Waterloo (1) (continuous rating)	Waterloo bus uprating completed, impact of this constraint is expected to become minimal
V>>S_NIL_KHTB2_KHTB1	$239,279 7.42 hrs	Prevent Keith -Tailem Bend #1 line overload for Keith - Tailem Bend #2 line trip	Short-term/ real-time line ratings currently under investigation
S>V_NIL_NIL_RBNW	$142,234 141.0 hrs	Avoid overloading North West Bend to Robertstown 132kV line for no contingencies	Short-term/ real-time line ratings currently under investigation
S>>V_NIL_SETX_SETX	$117,467 214.0 hrs	Avoid overloading a South East 275/132 kV transformer on trip of the remaining South East 275/132 kV transformer	Market benefit of installing the 3rd transformer in the South East earlier than otherwise required being investigated
V>>S_NIL_NIL_SGKHC	$114,365 5.08 hrs	Limit all other generators except LB3 to avoid overload of Snuggery-Keith 132kV line above continuous rating on trip of Nil	Short-term/ real-time line ratings currently under investigation
S>>V_RBTU_N-2_RBTX1	$113,207 2.58 hrs	Avoid overload of Robertstown transformer #1 on trip of Robertstown-Para and Robertstown-Tungkillo 275kV lines with Robertstown transformer #2	Currently under further investigation.

Source: Table 3.1, South Australian Annual Planning Report 2011, ElectraNet

The South Australian APR does not explicitly note recently completed and currently committed projects. However ElectraNet does report that it was actively engaged in the following initiatives in 2010-11[27]:

- Finalisation of the South Australian Interconnector Feasibility Study, jointly undertaken with AEMO, to investigate the technical and economic feasibility of a range of transmission development options to increase the interconnector transfer capability between South Australia and other NEM load centres (see Section 4.3.2 for further information);

[27] Page xiv, South Australia Planning Report 2011, ElectraNet

- Increase of the upper limit on the combined South Australian Heywood and Murraylink Interconnection export capability from 420 MW to 580 MW;
- Heywood Interconnector import capability study to investigate the nature of constraints limiting power transfers below the existing nominal capacity of the interconnector. This work has identified potential solutions which ElectraNet is now actively investigating[28]; and
- ElectraNet and AEMO have progressed work on the incremental upgrade of the Heywood interconnector. ElectraNet and AEMO will jointly commence a RIT-T process in 2011-12 (see Section 4.3.3 for further details).

The South Australian APR discusses various strategies to increase the utilisation of the existing network. These include:

- Segregation of the 275kV and 132kV networks (particularly in relation to the South East system);
- Un-meshing of the South East 132kV transmission system; and
- Reviewing existing transmission line ratings including removing any equipment limitations preventing lines achieving their as-built rating, the application of short term or dynamic line ratings and uprating a line if economically justifiable.

Table 4-8 lists the proposed and longer term possible transmission developments given in the South Australian APR which have been identified as being related to inter-regional flow limitations.

Table 4-8 SA – Future transmission developments related to inter-regional flows

Timing	Driver/s	Development
2014	Loss of the Murraylink interconnector under peak load conditions forecast to lead to inadequate 132kV voltages and the possibility of a Riverland wide voltage collapse.	Install one 15 Mvar 132 kV Capacitor Bank at Monash - ensures adequate reactive margins at Monash and Berri substations, also likely to provide market benefits in the form of improved Murraylink export limits from South Australia to Victoria.
2016-2020	Outage of Robertstown to North West Bend 132 kV #2 line overloads Robertstown-North West Bend #1 line (dependent on Murraylink import performance); voltages sag at Berri under contingency of Murraylink.	Construct a 275 kV double circuit transmission line from Robertstown to Monash; establish a 275/66 kV substation at Monash with 1 x 50 Mvar 275 kV reactor, 2 x 225 MVA 275/66 kV transformers and 1 x 240 MVA 275/132 kV transformer; construct a high capacity double circuit 66 kV line from Monash to Berri; remove all significant transmission infrastructure from Berri.
None given	Murraylink export from South Australia to Victoria is currently limited by the reactive support in the Riverland region – potential market benefits.	Install two 15 Mvar 132 kV capacitor banks in Riverland. One is at Monash and the other is at North West Bend.

[28] Pages 17-18, South Australian Annual Planning Report 2011

Timing	Driver/s	Development
None given	Insufficient Heywood capacity – potential market benefits if SA has lack of base load at times of peak load and installed wind generation exceeds 2300 MW.	Install 3rd Heywood transformer and associated work; such as • SVC • Series compensation • Reconfiguration of South East 132kV network

Chapter 10, South Australian Annual Planning Report, ElectraNet

In addition, the South Australian APR notes that the power transfer capability of Murraylink in the westward direction is expected to diminish by 5MW annually as the Victorian demand grows. The main limiting factor is the capacity of the Victorian transmission system to deliver power to Red Cliffs (the Victorian end of Murraylink). It is expected that this will cause overloading of the Robertstown-North West Bend 132kV line by around 2015/16. Network developments on the Victorian side of Murraylink may defer the need to extend the 275 kV from Robertstown to Monash by several years. ElectraNet and AEMO intend to undertake a joint analysis in consultation with TransGrid in 2011/12[29].

4.2.4 Tasmanian Annual Planning Report 2011 – Transend

The Tasmanian Annual Planning Report provides a schematic of the Tasmanian network indicating the number of dispatch intervals that a constraint was binding or violating over the period 1 Feb 2010 to 31 Jan 2011. However no information regarding the overall impact of the constraint on the network or in the market is given. The APR also lists the Tasmanian network constraints related to inter-regional flow identified in the 2010 NTNDP as binding for more than 100 hours in the year (shown below in Table 4-9).

Table 4-9 TAS – Tasmanian network constraints affecting Basslink flows listed in the 2010 NTNDP

Constraint equation	Description
V:T_NIL_BL_1	Transient stability at low TAS fault levels to avoid inverter commutation instability
T>>T_NIL_BL_EXP_7C	Thermal limit preventing post-contingent overload on Sheffield–Farrell 220 kV transmission circuit for loss of parallel Sheffield–Farrell 220 kV transmission circuit
V_T_NIL_FCSPS	Basslink limit from VIC to TAS for load enabled for FCSPS
T>>T_NIL_BL_220_6B	Thermal limit preventing post-contingent overload on Palmerston–Sheffield 220 kV transmission circuit for loss of a Sheffield–George Town 220 kV transmission circuit

Source: Page 26, Tasmanian APR 2011, Transend

Table 4-10 lists the current projects in Tasmania identified as relating to inter-regional flows.

[29] Page 99, South Australian Annual Planning Report 2011

Table 4-10 TAS – Completed, committed and planned augmentations related to inter-regional flows

Status	Augmentation	Details
Completed May 2011	Construction of the new Waddamana–Lindisfarne 220kV transmission lines	Increased the south to north transfer capability and resulted in changes to the NCSPS to make use of this increased capacity during Basslink export.
Committed – expected completion Jan 2014	George Town Substation 220 kV security upgrade – Stage 1	Currently has potential to cause wide spread loss of load which could exceed 850 MW as well as reduce operational flexibility and significantly constrain the transmission network.

Source: Chapter 4, Tasmanian APR 2011, Transend

Table 4-11 presents the network developments proposed by Transend to relieve the inter-regional constraints forecast to occur over the next five years[30].

Table 4-11 TAS – Proposed network developments (within 5 years) related to inter-regional flows

Proposed development	Details
Voltage support for George Town area	Significant amounts of generation as well as the Tasmanian end of Basslink connect to the George Town substation. Due to market behaviour, the output of generation and Basslink can be volatile. Thus voltage control at the substation is important. Further studies are being undertaken to determine the most appropriate location, size and time frame for Transend to install dynamic reactive power support devices in the George Town area.
George Town Substation 220 kV security upgrade – Stage 2	Follows on from Stage 1 of the George Town substation upgrade listed in Table 4-10.[31]

Source: Chapter 5, Tasmanian APR 2011, Transend

A direct upgrade of the flow path between Tasmania and Victoria was not analysed, although the 2011 Tasmanian APR noted that the addition of a second HVDC link between Victoria and Tasmania was a key component of the NEMlink conceptual project proposed by the 2010 NTNDP.

4.2.5 Victorian Annual Planning Report 2010 – AEMO

The Victorian APR reviews the performance of the Victorian transmission system over the recent past in a variety of ways. As part of this review, the top 20 constraints based on their market impact for 2009 and 2010 are listed (see Tables 3.6 and 3.7 in the APR).

Table 4-12 through to Table 4-15 on the following pages summarise the transmission network issues noted by the Victorian APR to be impacting the interconnector capability between Victoria and the other interconnected regions, along with measures being considered to address these issues and the project timeframe. Note that some of the constraints (included in *italics* for

[30] Constraint forecast studies conducted using Transend's 2011 medium growth, 10 per cent probability of exceedance (POE) demand forecast.

[31] The proposed augmentation will have no material inter-network impact. However it has been included here for the sake of completeness.

completeness) are not actually located within the Victorian region and are therefore not under AEMO's jurisdiction (on its role as JPB for Victoria).

A summary of the work related to interconnector upgrades currently underway is given below:

Murraylink – the constraint with the highest market impact in both 2009 and 2010 limits power flow from Victoria to South Australia (via Murraylink) to avoid potential voltage collapse. AEMO and ElectraNet, in consultation with TransGrid, intend to jointly assess efficient options for Riverland area supply, potentially involving augmentations in Regional Victoria;

Heywood – In 2010, AEMO and ElectraNet undertook a joint feasibility study to assess the benefits of increasing the transfer capability between Victoria and South Australia, looking at both incremental options to increase the capability of Heywood and new large augmentation options. See Section 4.3.2 and for more information regarding this study. A follow on study focused on an incremental upgrade of the Heywood interconnector is described in Section 4.3.3

Vic-NSW – The report also notes that in the Northern Corridor, the market impact of network limitations is forecast to be minor over the next five to ten years, potentially restricting Vic-NSW interconnector power flows in the New South Wales to Victoria direction. The limitations are not forecast to cause unserved energy over this period, but will be reassessed with any increase in import capability from New South Wales. AEMO states that it has not assessed the benefits of upgrading the Victoria-New South Wales interconnector in detail for the 2011 Victorian APR. However AEMO will continue to work with TransGrid on potential augmentations as part of the NTNDP.

Table 4-12 VIC – NEM wide: Existing inter-regional transmission issues

Flow path/s restricted[32]	Limit / Constraint	Possible future measures	Status / Timeframe
Vic to NSW, Vic to SA, Qld to NSW	V::N_NILVxxx[33] – Transient instability following fault and a trip of a Hazelwood-South Morang 500 kV line.	Related constraint equations currently being assessed. Issue will then be re-assessed. Possible augmentations (installation of breaking resistors and/or SVCs) may be carried out.	Currently being assessed
Vic to NSW, SA to Vic (Heywood), Tas to Vic	South Morang Terminal Station 500/220 kV F2 transformer thermal overload.	Installation of new 500/330 kV or 500/220 kV transformer	Monitoring / 1-5 years
NSW to Vic, Vic to/from SA	Northern Corridor 330 kV and 220 kV line thermal overload.	Various network options depending on line[34]	Upgrades of selected lines to be assessed in near future
NSW to/from Vic, Vic to/from SA (Murraylink)	*Thermal overloading on certain lines in Southern NSW.*	*NSW region*	-
NSW to Vic, Vic to SA (Murraylink)	Dederang Terminal Station 330/220 kV transformer thermal overload.	Installation of new 330/220 kV transformer	Monitoring / >5 years

Source: Chapter 5, Victorian Annual Planning Report 2011, AEMO

Table 4-13 VIC – NSW: Existing inter-regional transmission issues

Flow path/s restricted	Limit / Constraint	Possible future measures	Status / Timeframe
NSW to Vic	Transient instability following a fault and trip of a number of 330 kV lines in Southern NSW and Northern Victoria.	Not mentioned	Not mentioned
	Voltage collapse following a trip of the largest Victorian generating system.	Installation of additional capacitor banks and controlled series compensation at Dederang and Wodonga Terminal Stations.	>5 years
	Voltage collapse following a trip of a Dederang-Murray 330 kV line.		
	Transient instability following a fault and trip of the Bayswater-Sydney West 330 kV line or the Bayswater-Regentville 330kV line	*NSW region*	-
NSW to Vic limited to 1900MW	Oscillatory instability for high power transfers from New South Wales to Victoria.	Not mentioned	Not mentioned

[32] Where a specific interconnector is not specified, all interconnectors for that flow path are implied.
[33] This equation ID represents the aggregated market impact due to six constraint equations namely: V::N_NILVA_BL_R, V::N_NILVB_BL_R, V::N_NILVC_BL_R, V::N_NILVD_BL_R, V::N_NILVE_BL_R and V::N_NILVF_BL_R. All of them serve the same purpose, to prevent transient instability for a fault and trip of a Hazelwood-South Morang 500 kV line.
[34] See Section 5.4.4, Victorian Annual Planning Report 2011, AEMO for further information

Flow path/s restricted	Limit / Constraint	Possible future measures	Status / Timeframe
NSW to/from Vic	Dederang-South Morang 330 kV line thermal overload.	Two network options are being considered for alleviating this limitation: • Up-rating the two existing lines between Dederang and South Morang to 82degC operation and series compensation • Installing a new (third) 330 kV, 1,060 MVA line between Dederang and South Morang with 50% series compensation to match the existing lines (subject to obtaining the necessary easement).	The market benefits of a network option are currently insufficient to justify augmentation. AEMO will monitor this limitation and reassess it at the time of additional generation or import capability from New South Wales.
Combined restriction on NSW to Vic and Murray generation	Dederang-Murray 330 kV line thermal overload.	Two network options are being considered for alleviating this limitation: • Installing a new (third) 330 kV, 1,060 MVA line between Murray and Dederang (subject to obtaining the necessary easement). • Installing a new (second) 330 kV line from Dederang to Jindera. This option requires widening the existing easement between Dederang and Jindera. Up-rating transmission lines in New South Wales will also be required.	The market benefits of a network option are currently insufficient to justify augmentation. AEMO will monitor this limitation and re-assess it at the time of additional generation in Northern Victoria or Southern New South Wales or any increase in import capability.
	Thermal overloading on certain lines in Southern NSW	*NSW region*	-

Source: Chapter 5, Victorian Annual Planning Report 2011, AEMO

Table 4-14 VIC – SA: Existing inter-regional transmission issues

Flow path/s restricted	Limit / Constraint	Possible future measures	Status / Timeframe
SA to Vic	Oscillatory instability for high combined Vic-SA (Heywood + Murraylink) power flows or high Vic to SA (Heywood) power flows	AEMO and ElectraNet to undertake RIT-T study of Heywood upgrade in 2011/12 (see Section 4.3.3)	
Vic to/from SA (Heywood)	Heywood Terminal Station 500/275 kV transformer thermal overload.		
Vic to SA (Heywood)	Transient instability following a fault and a trip of the Moorabool- Heywood 500 kV line.		
Vic to SA (Heywood)	*Transient instability following a fault and trip of one Northern Power Station generating unit when the South East Capacitor is out of service.*	*SA region*	-
Vic to/from SA	*Thermal overloading on certain lines and transformers in South Australia's South East Zone.*	*SA region*	-

Flow path/s restricted	Limit / Constraint	Possible future measures	Status / Timeframe
Vic to SA (Murraylink) during peak demand in Vic	V>SMLBAHO1 – Voltage collapse for loss of the Bendigo-Kerang 220 kV line	Possible installation of additional reactive support in regional Victoria (50 MVAr 220 kV switched shunt capacitor bank at Bendigo Terminal Station)	A market benefits assessment will be conducted in 2011/12. Additional new reactive support is not likely to be required prior to 2013/14.
	Voltage collapse for loss of the Darlington Pt-Buronga 220 kV line.		
	Thermal overloading on certain 220 kV and 66 kV lines in Regional Vic including Ballarat-Bendigo 220kV, Ballarat-Moorabool 220kV, Bendigo-Fosterville-Shepparton 220kV and Dederang-Glenrowan 220kV.	Upgrading or installing additional transmission lines in Regional Victoria	AEMO and ElectraNet, in consultation with TransGrid, intend to jointly assess efficient options for Riverland area supply, potentially involving augmentations in Regional Victoria.
	Thermal overloading on certain 132 kV lines in South Australia's Mid-North or Riverland Zones	*SA region*	
Vic to/from SA (Murraylink)	*Thermal overloading on certain lines in Southern New South Wales.*	*NSW region*	

Source: Chapter 5, Victorian Annual Planning Report 2011, AEMO

Table 4-15 VIC – Tas: Existing inter-regional transmission issues

Flow path/s restricted	Limit / Constraint	Possible future measures	Status / Timeframe
Tas to Vic	Transient instability following a fault and trip of the Farrell-Sheffield 220 kV line or of a Palmerston-Sheffield 220 kV line.	*Tas region*	-
	V>>V-HWLY_1, V>>V-HWLY_2, V>>V-HWLY_3 Thermal overloading on the remaining Hazelwood-Loy Yang 500 kV line during a prior outage of a Hazelwood-Loy Yang 500 kV line.	Two network options are being considered for alleviating this limitation: • Two additional circuit breakers at Loy Yang and one additional circuit breaker at Hazelwood at an indicative cost of $14 million. • A new (fourth) 500 kV line between Hazelwood and Loy Yang at an indicative cost of $68 million (excluding easement cost).	The market benefits of a network option are currently insufficient to justify augmentation. AEMO will monitor this limitation and re-assess it at the time of additional generation or import capability around the Latrobe Valley 500 kV transmission network.
Vic to Tas	Low Tasmanian fault level – Inverter commutation instability	*Tas region*	-
	FCSPS limit – Frequency instability	*Tas region*	-
Tas to/from Vic	Thermal overloading on certain 220 kV lines in Tasmania.	*Tas region*	-

Source: Chapter 5, Victorian Annual Planning Report 2011, AEMO

4.2.6 Commentary regarding Annual Planning Reports

The APRs are independently prepared by the regional JPBs and as such are diverse in content, methodology, structure and the level of detail provided. Some commentary from a user's perspective regarding the varying approaches taken by the different APRs is given below. This report has not attempted to fully assess the adequacy of the various APRs.

For brevity, JPBs and their respective APRs are referred to by the abbreviation of their region:

- **Graphical representations of network:** Network schematics are provided in all APRs (although only on a zonal level by Vic); Network maps (i.e. network diagram superimposed on a map) are provided by SA, Tas and NSW; single line diagrams are provided by Qld, SA and Tas; NSW is the only APR to provide a network diagrams with line numbers;
- **Review of current network performance**: Detailed assessments of network performance are provided by SA, Tas and Vic, a qualitative description of grid performance is provided by Qld, no review of current network performance is provided by NSW. IES notes that SA and Vic present listings of specific network constraint equations along with their binding hours, annual marginal value (market cost), impact of the constraint and commentary, which is very helpful in quantifying the sources of congestion. Vic also includes "snapshots" of two extreme loading conditions illustrating line loadings and ratings at the time and graphs of power transfer limits on interconnectors. The review by Qld describes transfer capability across cut sets of constraints with no information regarding the location or cause of congestion provided;
- **Review of future limitations and projects (1-5yrs):** Extremely detailed descriptions of expected constraints in the short term along with proposed solutions are provided by SA, Tas and Vic. This includes project costs, timing, status, network and non-network options considered and other comments. Vic also provides forecast loading, market impact, economic evaluation of project and expected impact on network performance. NSW and Qld also discuss expected constraints and projects on a less detailed level than other jurisdictions;
- **Review of long term projects (5+yrs):** NSW provides a detailed discussion of long term projects, SA provides single line diagrams illustrating a 20 year development plan (on a regional and zonal basis) with notes and descriptions. SA and Vic both provide tables of long term limitations along with indicative solutions, costs and timing/triggers. Qld provides some less detailed information regarding projects in the long term. Tas notes that there are no advanced projects described in its 2011 APR;
- **Response to AEMO NTNDP:** All APRs, other than Qld, present tables of NTNDP recommended development projects and TNSP comments. In the case of SA, Tas and Vic, along with the tables they provide references to

more detailed responses elsewhere in their documents. The NTNDP is also referenced where appropriate throughout the documents. Qld describes the relationship between the NTNDP and APRs in the planning process, although it provides limited links between the various relevant NTNDP development projects and the various augmentations being proposed.

Additional comments:

- **Ease of finding information:** IES noted that locating and matching up information between multiple sources is substantially easier when information is provided by geographical area and in a structured manner (for instance, with main points summarised in tabular form rather than document text);
- **Electronic document:** The presence of bookmarks (i.e. a content list shown in the side panel of the PDF document) was found to be extremely helpful in navigating through an APR during the review. IES notes that bookmarks are enabled in the Qld, SA and Vic APRs, but not the NSW or Tas APRs.

IES concludes by noting that undertaking a review of transmission planning is challenging due to the diversity of style and detail across the APRs. Such a review would be greatly aided by the reports taking on a more consistent document structure and approach. In particular, the level of detail regarding current network performance, expected limitations and future projects varies greatly between APRs.

4.3 Interconnector Upgrade Studies

A number of studies regarding future interconnector upgrade options have been completed recently, are currently underway, or are expected to commence in the near future. This section gives a brief overview of these studies.

4.3.1 QNI – Powerlink and TransGrid

Powerlink and TransGrid published a Final Report in October 2008 relating to the potential upgrade of the QNI interconnector.[35]. This report found that the most plausible scenario for such an upgrade was 2015/16. On the basis of this, it concluded that it was premature to recommend an augmentation to the QNI at the time. A number of market developments has since occurred including development of the South-Eastern Queensland transmission system which has raised the voltage control limits, revision of the limit equations describing the NSW-Qld transient stability power transfer capability, various mooted generation investments, the Large scale Renewable Energy Target (LRET) scheme and recent introduction of the Regulatory Investment Test for Transmission (RIT-T).

Powerlink and TransGrid have therefore commenced an investigation of the economic viability and optimum timing of various upgrade options to the QNI interconnector based on the methodology of the RIT-T. This report is scheduled

[35] http://www.powerlink.com.au/asp/index.asp?sid=5056&page=Network/development&cid=5259&gid=326

for publication in the second half of 2011. Depending on the results of this analysis, Powerlink and TransGrid may decide to formally progress an upgrade through the National Electricity Rules process[36,37].

A high capacity 500kV double circuit project consistent with NEMLink was included as part of the suite of options within the QNI upgrade investigation.

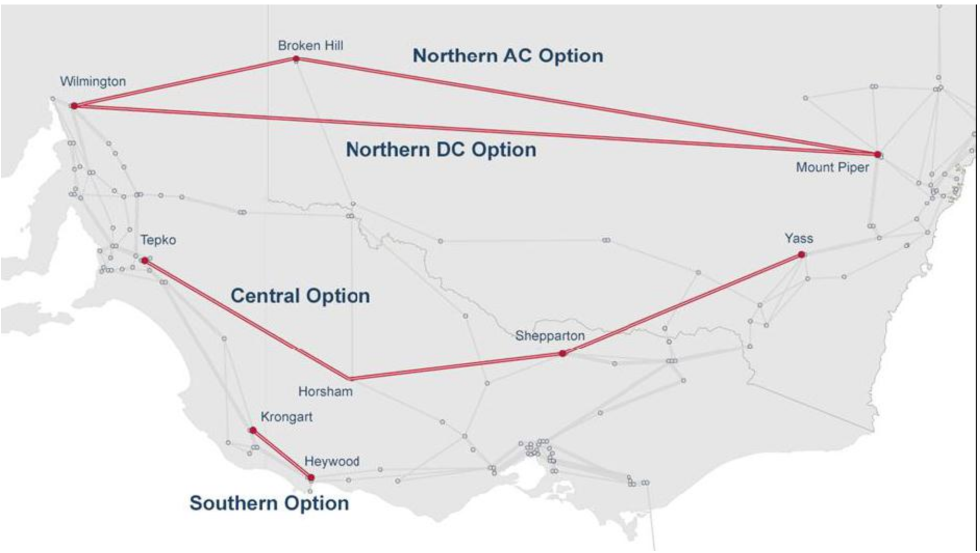
4.3.2 South Australia to other NEM regions – ElectraNet and AEMO

ElectraNet and AEMO undertook a joint feasibility study into transmission development options from South Australia to the other NEM load centres[38]. A number of options to enhance transmission capability were considered, ranging from incremental upgrades of existing interconnectors to major new high-capacity interconnectors between South Australia and the eastern states. The new high-capacity options considered are shown in Figure 4-1.

The study compared the total costs of meeting NEM demand with the existing interconnection capacity between South Australia and the other NEM regions to a number of options to increase the interconnection capacity. It was found that there was potential for augmenting transmission capacity between South Australia and the rest of the NEM in order to facilitate export of South Australian renewable energy as well as support the South Australian peak demand as the level of intermittent generation increases.

The study also recommended that AEMO and ElectraNet investigate the lower cost incremental upgrade options on a more detailed level in a follow on project (see Section 4.3.3).

Figure 4-1 New high capacity interconnector options considered by AEMO-ElectraNet Joint Interconnector Feasibility Study



[36] Page 62, New South Wales 2011 Annual Planning Report, TransGrid
[37] Page 82, Queensland 2011 Annual Planning Report, Powerlink
[38] ElectraNet-AEMO Joint Feasibility Study Final Report, February 2011, available at www.electranet.com.au/network/transmission-planning/interconnection-studies

4.3.3 Heywood Interconnector – AEMO and ElectraNet

The AEMO-ElectraNet Joint Feasibility Study (discussed in Section 4.3.2) indicated that a relatively low cost incremental upgrade of the Heywood interconnector could deliver net market benefits and be economically justified as early as 2017-18, depending upon the future scenario considered.

Follow-on studies looking at augmentation of the Victoria-South Australia (Heywood) interconnector and the transmission networks in south-east South Australia indicated that there may be sufficient market benefits to justify an incremental Heywood augmentation between 2013/14 and 2017/18[39]. This would increase the interconnector's notional capability from 460 MW to approximately 650 MW (based on the design thermal capacity of the existing 275 kV transmission lines between Heywood in Victoria and the South East Substation in South Australia).

AEMO and ElectraNet intend to assess this incremental upgrade option through a joint RIT-T process in 2011/12[40].

[39] This later analysis shows greater market benefit and an earlier implementation than the higher-level joint feasibility study. This is partly due to assumptions made in the joint feasibility study that reduced the augmentation benefits observed. For example, the joint feasibility study was a high level study that did not capture certain network limitations, particularly the voltage stability limits currently limiting power transfers, leading to higher than actual base case power transfer capacity, resulting in reduced augmentation benefits. The joint feasibility study also used average wind farm capacity factors, and so did not capture benefits during high wind outputs.
[40] Section 4, South Australian Annual Planning Report 2011, ElectraNet

4.4 Summary

Table 4-16 below repeats the summary of interconnector upgrades recommended in the 2010 NTNDP (first shown in Table 4-1) along with information published in the 2011 APRs related to these augmentations.

Table 4-16 Interconnector upgrades recommended by the 2010 AEMO NTNDP and related projects described in 2011 APRs

Inter-connector	NTNDP timeline	Suggested augmentation	Proposed projects described in APRs
QNI	Early attention	Series compensation on Armidale-Dumaresq 330kV circuits and Dumaresq-Bulli Creek 330kV circuits[41]	Powerlink and TransGrid have commenced an investigation of the economic viability and optimum timing of various upgrade options to the QNI interconnector based on the methodology of the RIT-T. (see Section 4.3.1)
Vic-NSW	Preparatory work	Installing a phase shifting transformer (TX) on the 220kV Buronga-Red Cliffs circuit.	The NSW 220kV system has a relatively high thermal rating compared to the voltage control capability. The feasibility of a phase shifting transformer (PST) installation is under investigation. TransGrid and AEMO will investigate the impacts of high Murraylink power transfers on the NSW and Victorian systems in the Buronga – Red Cliffs area.
Vic-NSW	Preparatory work	Additional transformers at Dederang and South Morang, a phase angle regulator on the Jindera-Wodonga circuit and series capacitors on the Eildon-Thomastown and Wodonga-Dederang circuits. Uprating the Eildon-Thomastown and South Morang-Dederang circuits, and cut-in of the Rowville-Thomastown circuit.[42]	Network options being considered include: • Installation of additional capacitor banks and controlled series compensation at Dederang and Wodonga Terminal Stations. • Up-rating the two existing lines between Dederang and South Morang to 82degC operation and series compensation • Installing a new (third) 330 kV, 1,060 MVA line between Dederang and South Morang with 50% series compensation to match the existing lines (subject to obtaining the necessary easement). • Installing a new (third) 330 kV, 1,060 MVA line between Murray and Dederang (subject to obtaining the necessary easement). • Installing a new (second) 330 kV line from Dederang to Jindera. This option requires widening the existing easement between Dederang and Jindera. Up-rating transmission lines in New South Wales will also be required.
Vic-SA	None given	Additional transformers at Heywood and South East substations, a shunt capacitor bank at the South East substation and utilisation of line design ratings for relevant circuits in the SESA zone and Eastern Hills. Above augmentation for Vic-SA as well as series compensation on 275kV Tailem Bend-SE circuit.	AEMO and ElectraNet to undertake RIT-T study of Heywood upgrade in 2011/12 (see Section 4.3.3)

[41] As proposed by the Powerlink in its 2010 APR, Chapter 5, Section 5.2.3.
[42] For more information, see pages 101-102, 2010 NTNDP, AEMO.

5 Conclusions

This report has compared the TNSPs' Annual Planning Reports (APRs) with opportunities that AEMO has identified for upgrading inter-regional transfer capabilities in the NTNDP to check whether there were any forecasts of congestion or upgrade opportunities that AEMO had identified which were not being pursued. In particular IES:

- analysed the 2010 NTNDP and 2009 NTS published by AEMO with respect to the inter-regional transmission upgrade opportunities noted in these reports;
- reviewed the TNSP APRs and any other relevant TNSP documentation, focusing on the planning initiatives related to inter-regional network development; and
- identified any "gaps" where a TNSP has not responded adequately to planning opportunities identified by AEMO in its NTNDP and NTS.

The AEMO NTNDP stated that a transfer capability upgrade between the SWQ and NNS zones (via QNI) would be likely to deliver net market benefits. On this basis, AEMO recommended early attention be given to an upgrade of the QNI interconnector. In response to this, Powerlink and TransGrid have commenced an investigation of the economic viability and optimum timing of various upgrade options to the QNI interconnector based on the methodology of the RIT-T. This report is due to be released in the second half of 2011.

Also, the AEMO NTNDP indicated that upgrades of the other interconnectors are not required at the present time, although preparatory work would be advised in some cases. TransGrid, AEMO (as JPB for Victoria) and ElectraNet all reported in their respective APRs that they will be undertaking investigations of their networks with a view to monitoring and assessing future potential upgrades of the inter-regional flow paths.

IES advises that, in our opinion, all the high level projects related to inter-regional transmission planning raised by the AEMO NTNDP appear to be being addressed by the relevant jurisdictional planning bodies. Consequently, IES considers that there is no indication of any planning shortfall regarding inter-regional transmission which might require the exercise of the Last Resort Planning Power (LRPP). Accordingly, IES recommends that no further analysis is required.