BASSLINK - AN HVDC INTERCONNECTOR BETWEEN TASMANIA AND THE AUSTRALIAN MAINLAND

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General Description

Basslink is a major Australian energy initiative that will allow the exchange of electricity between the island state of Tasmania and the mainland states of Australia. The HVDC interconnector project comprises a monopolar metallic return scheme, with a rated DC voltage of 400 kV, a rated DC current of 1250 A and a rated continuous power of 500 MW. Additionally, the HVDC system has a dynamic power transfer capacity of up to 630 MW from Tasmania to Victoria to meet Victorian peak demands.

This map of the interconnector route shows the location of the two converter stations at their points of connection to the existing AC systems; at George Town in the North of Tasmania, and Loy Yang near Traralgon in Victoria. Although initially considered to have sea electrodes, in order to eliminate perceived environmental impacts caused by the return current flowing through the electrodes and sea, a medium-voltage return cable was subsequently introduced making Basslink the longest monopolar system with metallic return to date.

At times when Victorian demand is high, Tasmania is expected to export energy to Victoria since the peak generating capacity is inadequate, whilst under-utilized baseload generating capacity in Victoria will be able to provide off-peak power to Tasmania which is energy-constrained by rainfall in hydro catchments.
Brief History

The Tasmanian Government initiated work in the mid-1990s on an energy strategy, which included the development of Basslink. The Basslink Development Board (BDB) was established in 1998 by the Tasmanian Government to facilitate the development of Basslink. The BDB awarded the contract to build, own and operate Basslink to National Grid International Ltd, a wholly owned subsidiary of National Grid Group plc (now National Grid Transco plc) of the UK in January 2000 (the contract has since been novated to Basslink Pty Ltd - BPL).

Basslink, having been subject to extensive environmental assessments and planning processes, gained approval from the Australian Federal Government and Victorian and Tasmanian State Governments in 2002. Basslink will take three years to construct, with commissioning planned for November 2005.

Further information regarding the Basslink Project can be found at www.basslink.com.au.

Main Participants

A consortium of Siemens Ltd and Pirelli Cables will construct the project that will connect the transmission networks of SPI PowerNet (in Victoria) and Transend Networks (in Tasmania). Arrangements are in place between Hydro Tasmania (the major generator in Tasmania) and BPL to underpin the commerciality of the Basslink project.

Basslink is a fundamental business strategy for Hydro Tasmania. It enables Hydro Tasmania to capitalise on the synergies between its hydro generation system and development of world-class renewable wind resources. It also enables Hydro Tasmania to capitalise on the trading synergies between Tasmania and mainland Australia. Basslink provides substantial drought proofing of Tasmania’s electricity system and enables Tasmania to join the National Electricity Market. Basslink and entry into the National Electricity Market enable Hydro Tasmania to convert risk due to rainfall variation into more manageable market risk.

Connecting AC Systems Description

Tasmania

The Tasmanian maximum demand occurs during winter and is near 1700 MW. The minimum demand occurs during summer and is near 900 MW. Being a hydro generation based power system Tasmania has significant excess of generation capacity over the maximum demand. Installed capacity comprises 2,400 MW of hydro, 240 MW of thermal and 60 MW of wind based generation.

Transend’s transmission network comprises 3,500 km of overhead transmission line circuits and 43 substations operating at 220 kV and 110 kV. The transmission network has been designed to support extreme generation scenarios to cater for the diversity in hydro generating that is dependent upon stochastic water inflows. The diagram shows the backbone 220 kV system. The 110 kV network supports the 220 kV network and provides radial connections to loads.

The point of connection of Basslink to the Tasmanian power system, George Town substation, has a current maximum demand of 420 MW and is supplied by two main transmission corridors. These corridors connect George Town to two large hydro based generation sources, one a combination of generation located in the north-west and the west of Tasmania, the other central and southern Tasmanian generation.
The maximum demand at George Town will increase from 420 MW to 1050 MW. It is not planned to augment the existing transmission system to support the additional demands placed upon it by Basslink. This is possible because simultaneous generation from the western and eastern Tasmanian sources can meet Basslink export expectations and it is proposed to utilise the security capability of the transmission network.

**Victoria**

The majority of the generation in Victoria is from brown coal power stations, which operate most efficiently at continuous high power output.

The Victorian power system has a peak demand of the order of 9000 MW and in addition, there are interconnections to the power systems of South Australia and New South Wales. Basslink will be connected to the Victorian power system at the Loy Yang power station 500 kV switchyard. Since this is a major generating site with over 3000 MW of capacity and there is other significant local generating capacity, the Loy Yang converter station can be considered to be connecting to a very strong system. Because of this, the likelihood of problems occurring that can be associated with the connection of an HVDC converter is much reduced. This is in stark contrast to the situation in Tasmania as described below.

**Effects and Challenges of Basslink**

The magnitude of proposed Basslink transfers in relation to the current Tasmanian demands presents a number of engineering challenges to ensuring power system security, meeting quality of supply requirements, and to asset maintenance practices. In particular:

1. A number of transmission corridors will be operated beyond their “N-1” capabilities.
2. Sudden de-load of the link has to be catered for.
3. High asset loadings on high temperature days will occur.
4. Meeting quality of supply standards given the number of existing disturbing and harmonic producing loads. George Town substation supplies an aluminum smelter, a smelter comprising submerged arc furnaces, and a small retail load including wood chip mills and an under ground mine.
5. Meeting voltage requirements whilst changing from full flow in one direction to full flow in the other direction represents over a 1,000 MW swing.
6. The fault level at George Town substation varies from an estimated maximum of 3,100 MVA with 2,240 MW of generation required to support 630 MW of export, to 1,350 MVA with 500 MW of generation during import.

The proposed high levels of Basslink transfers in relation to the Tasmanian load means that frequency control within the Tasmanian power system following sudden loss of or de-load of Basslink is a key issue. The magnitude of Basslink transfers in relation to the local load in combination with hydro based turbine governor response means even after taking into account natural load frequency dependencies it is insufficient to rely upon conventional frequency controls. For example with 300 MW of import, approximately 3000 MW of synchronised generation is required to provide sufficient system inertia and frequency control to cover the loss of Basslink.

There are two options for maintaining a secure operating state of the Tasmanian power system:

1. To limit transfers across Basslink through the application of constraint equations, and;
2. To implement a System Protection Scheme (SPS) to ensure that the different dimensions of a secure operating state are met.

To limit transfers would have unacceptable commercial impacts, hence the necessity for the SPS. The SPS proposed comprises two fundamental components, one to maintain system frequency within standards, the other to maintain assets within operating ratings. These have been named the Frequency Control SPS (FCSPS) and the Network Control SPS (NCSPS) respectively. These are described in more detail later in this article.
The Basslink converter will have a control that modulates transfers depending upon the differences between power system frequency in the interconnected systems. The purpose of this control is to make Basslink look like a synchronous link and to facilitate a single national market in frequency control services. This controller is crucial to the utilisation of the security capability of the network and the removal of thermal overloads following loss of key transmission elements.

Role of the Project Developer’s Consultant

The trend in recent times for projects similar to Basslink has been for the project developer to write a relatively high-level functional specification against which the chosen Engineering, Procurement and Construction (EPC) contractor must perform. Whilst this places the responsibility for detailed equipment design with the EPC contractor, there are several other areas where the developer requires technical advice and direction to ensure their interests are protected. This capability can be sourced ‘in-house’, although the recent trend has seen such in-house capability reducing, if it existed in the first place, or through consultants working on the project developer’s behalf. For Basslink, both in-house capability and use of the expertise available within Shaw PTI has been made use of, as well as an Australian based consultant dealing with the more ‘local’ issues.

Technical advice and direction by Shaw PTI in assisting BPL has varied considerably from receipt of the Project Brief to now just one year before commissioning commences. The various areas where technical input has been given are outlined below, but at all times the three key factors have been: i) to understand what the developer really wants and/or needs  ii) to provide information in a form which is of most use iii) to be adaptable in meeting the evolving requirements as the project progressed.

1. General technical advice directly to BPL as requested including:
   a. Assessment of various AC system connection points. Some preliminary information was available on potential routes, but even so, there were five potential connection points in Victoria, and two in Tasmania, as well as a Basslink rating which was yet to be fixed. Careful assessment of all relevant technical, commercial, and environmental factors affecting each connection point is vital to ensure an optimal solution is reached whilst minimising the risk of ‘show-stoppers’ occurring.
   b. Assessment of alternative technologies. This included a comparison of the losses for bi-pole, metallic return, and sea-return configurations, as well as a review of ‘HVDC Light’ and consideration of various AC voltages and DC for the on-shore lines and cables in Victoria.
   c. Assessment of various risks associated with the project including a review of the adequacy of the Tasmanian generation and transmission to support 600 MW transfer, and of possible 500 kV system developments in Victoria.
   d. Initially providing guidance to, and more latterly due diligence of, BPL’s EPC contractor as required.
   e. Input to the Environmental Impact Assessment.

2. Addressing HT/Transend technical queries (involving BPL’s EPC contractor as appropriate) and reviewing the information supplied by them.

3. Obtaining a balance between the necessary requirements of the connecting AC systems owners/operators being met, and BPL’s interests being protected (involving BPL’s EPC contractor as appropriate). Examples of this were assistance with Connection Agreements, in particular fault level and reactive power requirement issues.

4. Detailed design of a System Protection Scheme (SPS). This was an unusual aspect of Basslink and has required the complete design from initial identification of the scheme requirements right through to implementation and is described in more detail below.
System Protection Scheme (SPS)

Overview

The diagram below shows the maximum Basslink export and import levels at the connection point in the Tasmanian system. It is immediately obvious that Basslink is going to have a major impact on the Tasmanian system when compared to the range of demands in Tasmania. This is especially so when it is considered that no additional transmission infrastructure is being incorporated because of Basslink.

The two fundamental areas where serious problems would occur if preventative action is not taken are excessive frequency deviations when Basslink is lost, and thermal overloading of transmission equipment. Two schemes have therefore been designed to allow Basslink to maximise power transfers whilst remaining within planning standards. The first is a Frequency Control SPS (FCSPS) which trips generation or demand in a controlled manner for Basslink exporting or importing respectively. The second is a Network Control SPS (NCSPS) which primarily trips or de-loads generation for Basslink exporting, but will also trip demand for some particular system conditions with Basslink importing.

The SPS is quite unusual in that it is actually a composite of SCADA and power system protection, and also because of the level of importance being attached to it. Confidence in the design and operation of the SPS is vital to avoid Basslink flows being potentially severely constrained which would quickly affect the commercial viability of the project. Because of this, a stated aim from the start was for the SPS design to be as simple as possible avoiding unnecessary complexity whilst still achieving all the desired objectives.

To assist in the SPS design, Transend provided detailed dynamic PSS/E models of the generators and their controllers and incorporating models of the DC converters and filter switching/tripping logic. They also provided 18 'boundary condition' load flows which were an attempt to simulate a boundary of onerous system conditions within which it could be expected the system would normally operate. These included conditions which either stressed the transmission system (for NCSPS design) and/or would lead to high frequency deviations for loss of Basslink (for FCSPS design).

FCSPS

- Design process

A large number of dynamic studies were carried out at various demand levels, Basslink transfers, and other system conditions to determine maximum frequency deviations and post-contingency voltages following loss of Basslink. For Basslink exporting, the required total amount of MW generation to trip to keep frequency within standards was determined along with any restriction on the location of this generation. Similarly for importing, the required amount and location of load blocks to trip were determined. However, whereas there was always sufficient generation available to trip, this was not the case with the load blocks where there was only a specified number available. This therefore meant that whilst the level of Basslink export as system demand varied was not limited, the amount of import was limited and decreased with falling demand effectively giving an upper boundary of feasible Basslink imports as demand varies.

In carrying out the above studies, two important factors became obvious. Firstly, that the upper boundary of Basslink imports was dependent on what generation was actually running at the time due to the significant differences in both generator inertias and governor responses; and secondly, that any attempt to control post-contingency voltages by some sort of centralised control by the FCSPS would require a high degree of complexity. The outcome of this is that whilst the FCSPS will determine the amount of generation or load blocks to trip as system demand and Basslink flow varies, to avoid it becoming overly complex, the roles of voltage control and determination of the upper
boundary of Basslink imports have been taken out of the FCSPS. The former will now be addressed by the implementation of local Automatic Voltage Control (AVC) schemes where required, and the latter by 'on-the-day' calculations by the System Operator, the National Electricity Market Management Company, NEMMCO.

- Implementation

Using the information determined from the above, tripping logic in the form of flow-charts was written for both generating unit and load block tripping. Given a list of prioritised generators or load blocks available for tripping, the logic determines which generators or load blocks to trip consistent with achieving the required aims as system conditions vary. The selected generators or load blocks are then pre-armed ready for immediate tripping should a 'loss-of-Basslink' signal be detected. Up-dating of these tripping lists occurs every 4 seconds. Practically, the logic is implemented in hardware as an addition to Transend’s SCADA Network Operation and Control System (NOCS).

NCSPS

- Design process

Transend supplied circuit and equipment rating information which led to three different levels of potential overload following the loss of a relevant circuit. The most onerous was whether short-term equipment ratings could be exceeded. Equipment was given a 10 second rating such that the current flowing through it must be lower than the value given within 10 seconds of the overload occurring. The next level was whether circuit dynamic ratings could be exceeded, up to 15 minutes. If so, the circuit current was required to be brought within the continuous rating. The final level was that if 15 minute dynamic ratings would not be exceeded, then no action was necessary on the basis that this gave sufficient time for action by the System Operator.

Several circuits were identified as having the potential for overloading following the loss of pertinent other circuits. Most of those involved the circuits as shown above in the simplified diagram of the Tasmanian transmission network. For each of the identified circuits, a large number of load flows were carried out to determine maximum pre- and post-contingency currents, and the pre-post-contingency current ratio for a range of pre-contingency currents and other system conditions where appropriate. This identified whether any NCSPS action could be required, and if so, whether it needed to be fast to meet the 10 second rating, or slow to meet the 15 minute rating. Fast action would necessitate tripping of generation, whilst slow action would only require generators to be sequentially de-loaded over a period of time to minimise impacts on the system and so that they could retain voltage control.

In addition, it was necessary to determine the effect on the currents in particular circuits of tripping specific generators which led to numerous 'MW reduction' ratios i.e. the ratio of the amount of reduction in the flow in a particular circuit to the amount of generation tripped/de-loaded. These ratios were obviously dependent on system conditions, in particular for any pre-contingency outage conditions considered.

- Implementation

Using the information determined from the above, tripping logic in the form of flow-charts was written primarily for generating unit tripping, but also for load block tripping for limited circumstances. Given a list of generators (or load blocks) available for tripping or de-loading, the logic determines which generators (or load blocks) to trip and/or de-load consistent with achieving the required aims as system conditions vary. On detection of the loss of a relevant circuit, the selected generators (or load blocks) are sent tripping or de-loading signals as appropriate. Up-dating of the tripping/de-loading lists occurs every 4 seconds. As with the FCSPS, practically the logic is implemented in hardware as an addition to the NOCS.
Summary

Basslink integration into the Tasmanian Power System represents major engineering and power system operation challenges that has required very close cooperation between many parties including BPL, Siemens, Hydro Tasmania, Transend, the Tasmanian Government, and the national power system operation, the National Electricity Market Management Company (NEMMCO). In particular, the high magnitude of Basslink power relative to the Tasmanian system capacity has required the careful design of a novel System Protection Scheme in order to avoid potentially severe constraints on Basslink flow.

The success of meeting these challenges so far is demonstrated by the planned commissioning date of November 2005 currently being on-track.