TECHNICAL REPORT

OPTIMISING THE LATROBE VALLEY TO MELBOURNE ELECTRICITY TRANSMISSION CAPACITY

FEBRUARY 2002

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1) Introduction

VENCorp has undertaken a review of the power transmission capacity between the Latrobe Valley and Melbourne. This review indicates that the transmission capability can be optimised in an economic manner by augmenting the transmission network.

The benefits of optimising the power transmission capacity between the Latrobe Valley and the Melbourne metropolitan area include:

1) Reduction in transmission active power losses

2) Reduction in the amount of generation re-scheduling and potential load shedding due to transmission constraints during both planned and unplanned outages

3) Reduction in reactive power losses under heavy system loading, which reduces the requirement to install new reactive plant.

VENCorp has initiated a consultation process with regard to the options for achieving this optimisation. The details of that consultation, together with an overall discussion of the key issues associated with the proposed optimisation area contained in the report "C*onsultation Paper on Optimising the Latrobe Valley to Melbourne Electricity Transmission Capacity".*

This report outlines the limitations of the existing transmission system, and outlines a number of possible development options to optimise the capacity of the transmission system that are likely to satisfy the required regulatory tests for transmission augmentations.

The accompanying report "*Economic Evaluation on Optimising the Latrobe Valley to Melbourne Electricity Transmission Capacity"* describes in more detail the assessment methodology, market development scenarios, simulation data, net benefit analysis and recommendations for optimisation.

In accordance with clause 5.6.2 of the National Electricity Code, all transmission investment must satisfy the regulatory test as promulgated by the ACCC in December 1999. Clause 5.6.2(g) of the code states that;

> Each *Network Service Provider* must carry out an economic cost effectiveness analysis of possible options to identify options that satisfy the regulatory test, while meeting the technical requirements of schedule 5.1 of the *Code* and where the *Network Service Provider* is required by clause 5.6.2(f) to consult on the option this analysis and allocation must form part of, the consultation on that option.

2) Existing Transmission Network

The existing Victorian transmission network is shown in Figure 1 and Figure 2.

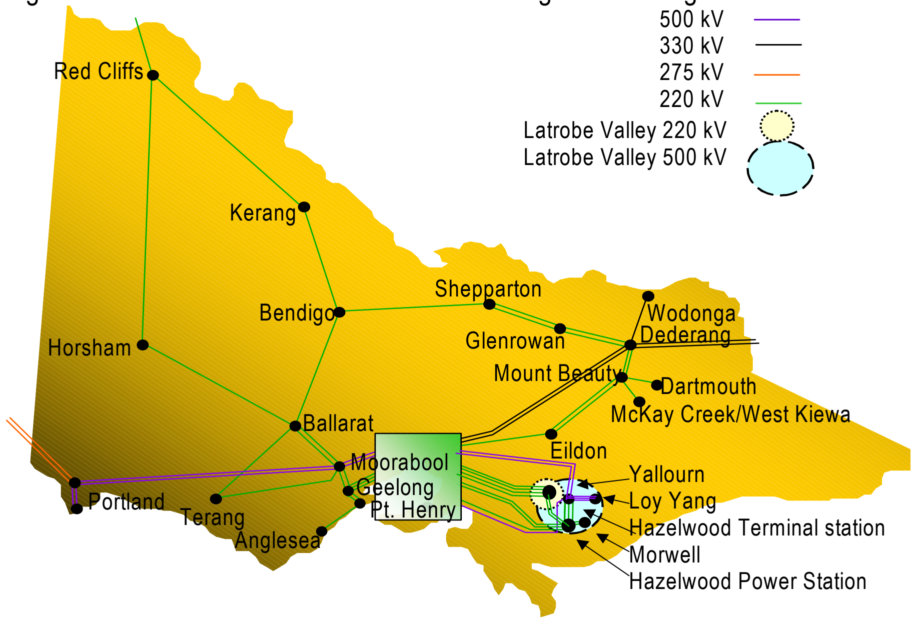

Figure 1: Victorian Transmission Network

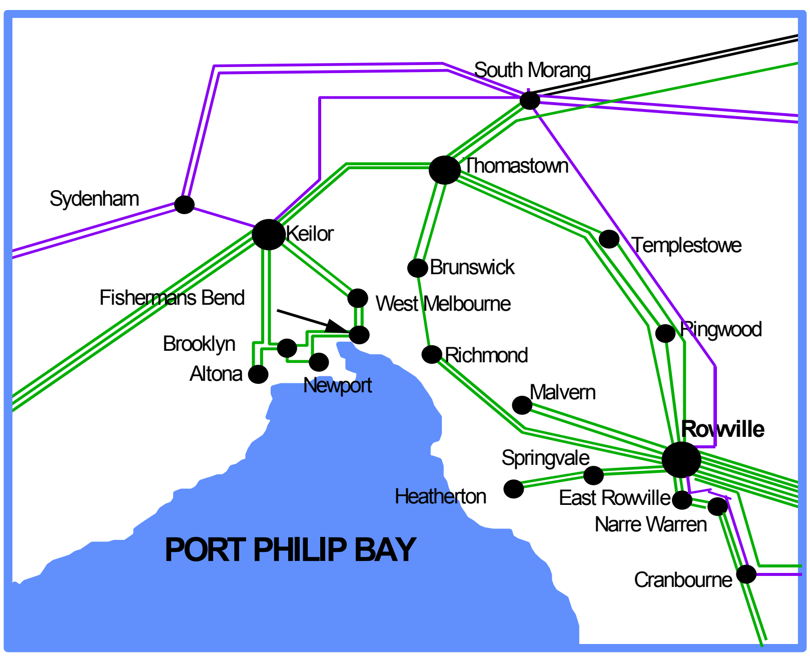

Figure 2: Melbourne Metropolitan Transmission Network

Two transmission voltage levels are being used between the Latrobe Valley and Melbourne.

220 kV: There are six transmission lines built at 220 kV between the Latrobe Valley and Rowville Terminal Station (ROTS), the main 220 kV receiving station in Melbourne's

outer east. The transmission distance along the shortest 220 kV route from the Latrobe Valley to Rowville is about 105 km.

500 kV: There are four 500 kV transmission lines built between Hazelwood Terminal Station (HWTS) in the Latrobe Valley, and South Morang Terminal Station (SMTS) in Melbourne's northeast. These four 500 kV lines run along two different routes. Two of these lines follow the more northerly direct route to South Morang (155 km). The other two follow the southern route, passing through Cranbourne, Narre Warren and Rowville Terminal Station (ROTS). This route is approximately 175km long from HWTS to ROTS and finally to SMTS.

Only three of the four 500 kV lines transmit power at 500 kV, the other being operated at 220 kV as shown in Figure 3. This line is one of the two that runs on the southern route and passes through Rowville.

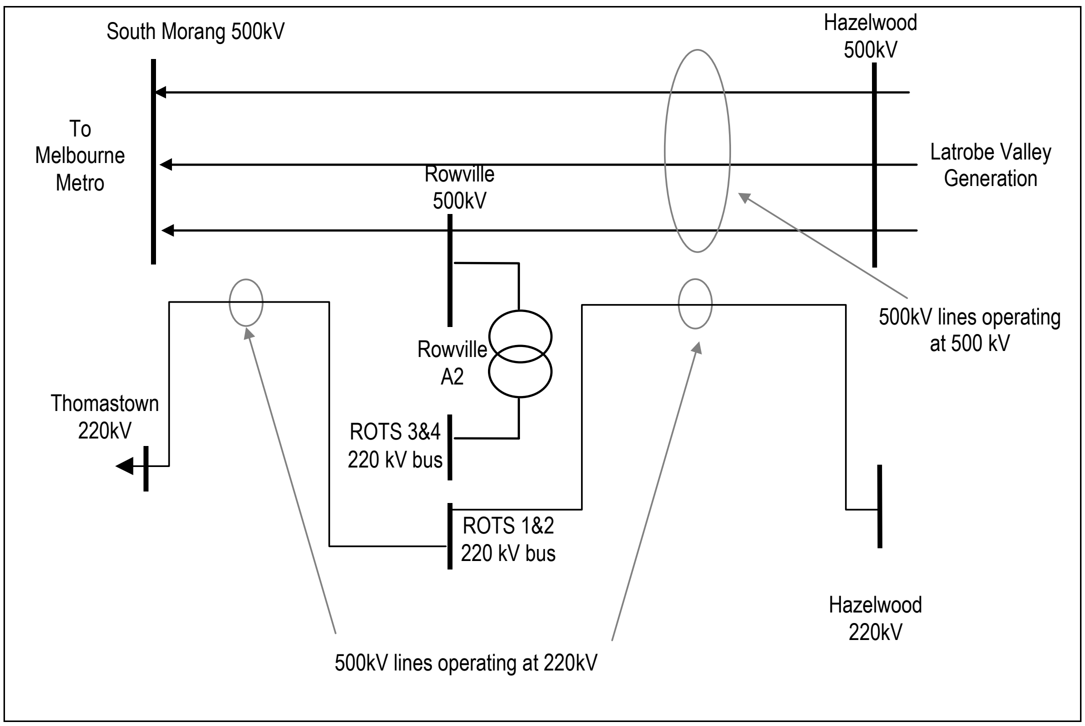

Figure 3: Latrobe Valley to Melbourne 500 kV transmission system, showing the 500 kV line operating at 220 kV

This line, constructed for operation at 500 kV, is currently used to form two different 220 kV circuits to ROTS: one from Thomastown Terminal Station (TTS) to ROTS, and one from Hazelwood Power Station (HWPS) to ROTS. The current line arrangements are;

- The HWTS to ROTS section of the 500 kV line, along with a short additional section of 220 kV line from HWPS to HWTS, is used to form the HWPS-ROTS No 3 220 kV line.
- The ROTS to SMTS section of the 500 kV line, along with an additional 220 kV section of line between SMTS and TTS, is used to form the ROTS-TTS 220 kV line.

At present, the lines are relatively under-utilised since for operation at 220 kV the applicable thermal ratings are significantly lower than those that would be during operation at 500 kV.

3) Latrobe Valley to Melbourne Transfer Capability

The 500 kV transmission network between the Latrobe Valley and Melbourne provides a strong connection between the Melbourne load centre and the Latrobe Valley, where approximately 85% of Victoria's generation capacity is located. Around 5860 MW can flow on the 500 kV network at times of peak generation in the Latrobe Valley. Since more than 90% of this generation uses relatively low cost brown coal as fuel, the transfer level remains very high.

As the Victorian demand grows, so too does the dependence on the Latrobe Valley generation and therefore the reliance on the transmission network connecting it to the major load centres. The power transmission capacity from the Latrobe Valley to Melbourne is determined by a combination of thermal limits, voltage collapse limits and transient stability limits. These limits have led to VENCorp investigating four transmission (network) alternatives and two non-network alternatives which aim to optimise the Latrobe Valley to Melbourne transfer capability.

The network alternatives considered are:

1) The "line termination upgrade option" which includes upgrading the terminations on the three existing Latrobe Valley to Melbourne 500 kV lines to increase their thermal capacity;

2) The "Rowville option" which includes conversion of the HWPS-ROTS No.3 Line from operation at 220 kV to operation at 500 kV, plus installation of a 1000 MVA, 500 kV/220 kV transformer at Rowville;

3) The "Cranbourne option" which includes conversion of the HWPS-ROTS No.3 Line from operation at 220 kV to operation at 500 kV, plus establishment of a new terminal station at Cranbourne and installation of a 1000 MVA, 500 kV/220 kV transformer; and

4) The "5th 500 kV line option" which includes construction of a new 500 kV line from the Latrobe Valley to Melbourne while retaining the existing 220 kV and 500 kV line arrangements.

The non-network alternatives considered are:

1) Demand Side Management (DSM); and

2) Additional generation to the west of the Latrobe Valley to Melbourne corridor.

Consideration is given to the different impacts these alternatives have on the following technical characteristics of the network:

- The ability of the Latrobe Valley to Melbourne network to support generation in the Latrobe Valley and therefore support the Victorian demand under all system normal and line outage conditions;
- The amount of transmission losses incurred by the network;
- The impact on voltage stability;
- The impact on transient stability
- The impact on fault levels;.

These alternatives have been considered based on performance criteria as outlined in Appendix 3.

3.1) 500 kV line thermal capacity

Under system normal conditions when all lines are in service, the 500 kV network is capable of securely carrying all the power output from the connected generation. However, during outages of a 500 kV transmission line, the loading on the remaining two lines will increase and under some conditions this will not result in the maintenance of a secure condition. In expectation of a subsequent outage, constraints may be placed on the amount of generation that can be run in the Latrobe Valley. Under the worst case scenario, this could result in a need to shed load.

Table 3-1 and Table 3-2 list the amount of 500 kV connected generation presently installed in the Latrobe Valley, and the existing capability of the 500 kV network to securely transfer this power to Melbourne. The existing capability of the 500 kV network listed below is limited by the thermal capacity of the lines.

Latrobe Valley 500 kV generation	**MW**
LYPS A	2000
LYPSB (including Valley power)	1300
HWPS	1600
JLPS	432
MPS	170
Bairnsdale	80
YWPS unit 1 (Transferred to 220 kV side)	0
Total generation	5582
Local/ In House Loads	606
Transfer to Melbourne area via 500 kV network	4976

Table 3-1: Existing Latrobe Valley 500 kV Generation

500 kV Network condition	**Capacity (MW)**
Firm transmission capacity with all lines available	5860
Firm capacity with one 500 kV line out of service	3430

Table 3-2: Capability of the 500 kV network

The difference between the firm capability of the 500 kV network with one line out of service, and the installed 500 kV generation indicates that up to 1550 MW of 500 kV generation would need to be constrained off under worst case conditions. This worst case scenario is outage of one of the 500 kV lines from the Latrobe Valley to Melbourne at a time of high demand and high ambient temperature, when all Latrobe Valley generation is likely to be in service and the lines are at their lowest rating. Firm capacity is the term used to define the acceptable transfer capacity while ensuring that network security is maintained in expectation of a subsequent outage.

For this scenario, the constraint on Latrobe Valley generation is likely to translate into load shedding in the order of 1050 MW when accounting for the 500 MW reserve margin that would have been available.

Any new generation or interconnections such as BassLink that depend on the Latrobe Valley to Melbourne 500 kV network would also be effected by the potential constraint during line outage conditions.

3.1.1) 500 kV line Planned Outages

At present, planned outages of the 500 kV lines between the Latrobe Valley and Melbourne (which are required for general maintenance) are scheduled under the following conditions to minimise the amount of generation constraint and avoid load shedding:

- During moderate and light demand periods with adequate generation reserves available from Snowy, New South Wales and South Australia.

- When network switching is carried out to allow all 500 kV and 220 kV lines between the Latrobe Valley and Melbourne to operate in parallel (which has the effect of increasing the 220 kV network loading while offloading the 500 kV network).

- During low ambient temperature periods as the rating of the six 220 kV lines from YPS to ROTS lines (two lines via HWPS) is too low during high ambient temperature periods for parallel operation with the 500 kV lines.

The window of opportunity for taking 500 kV line outages without imposing constraints on generation is becoming smaller, and any new generation or interconnections such as BassLink that depend on the Latrobe Valley to Melbourne 500 kV will decrease the opportunities even further.

3.1.2) Bush Fires or Severe Storms

Two of the three existing 500 kV transmission lines between the Latrobe Valley and Melbourne run in parallel through a single (northern) easement. Although the loss of both circuits from a single event is extremely unlikely, events such as a bush fire or severe storms in the vicinity of the transmission line easement may force both 500 kV lines to be switched off for safety reasons. The recent 2001/02 bushfires in NSW are an example of this where a number of parallel single circuits were tripped within seconds of each other.

As there is considerable chance for bush fire events to coincide with hot summer periods that lead to peak Victorian demands, the coincident outages of two 500 kV lines could be critical because the transmission capacity between the Latrobe Valley and Melbourne reduces to about 2250 MW. Based on current demand forecasts, this could translate in a need to shed up to 3700 MW of load.

3.2) Transmission losses

Transmission losses in Victoria for the financial year 2000/01 were 1330 GWh, or an average 152 MW. The corresponding average pool price was around $44.8, so that the value of the losses approached $60M.

Some of the alternatives considered by VENCorp in its review of the transmission capability between the Latrobe Valley and Melbourne reduce the amount of transmission losses in the network. A reduction in transmission losses effectively reduces the amount of generation required to support the demand and therefore saves fuel at the marginal generating unit.

Any reduction in transmission losses will provide an economic benefit to the market through lower dispatch prices, and will also reduce the emission of greenhouse gases.

3.3) Voltage collapse

Voltage collapse may occur following the sudden outage of a generator or a main transmission element. In addition to loosing a source of reactive power if a generator is tripped, such outages have the effect of increasing the loading on the remainder of the transmission system which increases the reactive losses and therefore the demand for reactive power. When the amount of reactive reserve available is insufficient to compensate for the increased reactive demand, there is a supply demand imbalance and voltage collapse may occur leading to unacceptably low voltage profiles and widespread uncontrolled load shedding. It is vital that the electricity system be operated so such events are avoided.

Voltage collapse is primarily critical during the summer peak demand periods due to the high real power demand combined with high reactive power demand from devices such as air conditioners.

Under conditions of low AES Yarra generation, voltage collapse induced by contingencies on the 500 kV transmission network between the Latrobe Valley and Melbourne defines the maximum supportable Victorian demand level for import levels up to 1500 MW.

Under conditions of high AES Yarra generation, voltage collapse induced by contingencies on the 500 kV transmission network between the Latrobe Valley and Melbourne only defines the maximum supportable Victorian demand level when import is less than 1150 MW.

On average, around 300 MVAr per year of shunt capacitors are added to the Victorian network to increase the supportable maximum summer demand level. The amount varies from year to year between 200 and 400 MVAr and any major transmission augmentations that influence the potential reactive power supply and demand balance may defer the requirement for additional shunt capacitors.

3.4) Transient Stability limit

A transient stability limit determines the Victorian export limit to Snowy/New South Wales and South Australia as shown in Figure 5. The critical fault for transient stability is a line fault close to the Hazelwood end of a Hazelwood-South Morang 500 kV line. At low Victorian demand levels the critical contingency changes to a fault close to the South Morang end of a South Morang-Dederang 330 kV line since line flows are reduced on the Latrobe Valley to South Morang.

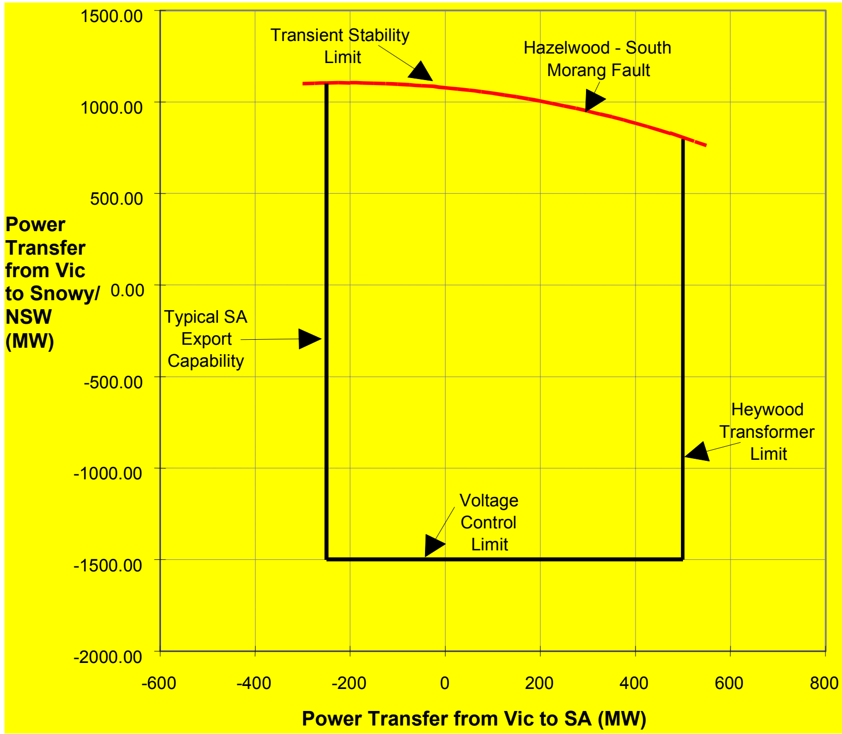

Figure 5: Victorian power transfer capabilities to Snowy / New South Wales and South Australia for a particular operating condition.

3.5) Summary

The Victorian power system and it ability to meet demand levels demand is heavily dependent on the 500 kV transmission network from the Latrobe Valley to Melbourne to connect base-load generation to the metropolitan load centre.

The existing capacity of the 500 kV network from the Latrobe Valley to Melbourne is sufficient to support the existing generation with all plant in service. However, the current capacity of the 500 kV network can lead to significant generation constraints following planned or forced outages of a 500 kV line primarily due the thermal capacity of the remaining lines.

The 500 kV network from the Latrobe Valley to Melbourne also can determine voltage collapse limits governing Victorian maximum supportable demand, and Victorian export limits based on transient stability.

Transmission losses on the 500 kV network are significant, and increasing due to both new generation and forecast load growth.

4) Alternative 1: The Line Termination Upgrade

This augmentation involves upgrading the terminations of the Hazelwood to Rowville and Hazelwood to South Morang 500 kV lines to match the conductor rating.

Currently, line traps limit the overall thermal rating on these three lines to between 20% and 30% below the conductor rating, as shown in Table 4-1:

Line	Ratings at 35°C / 5°C, respectively	
	Terminations	Conductor
HWTS-SMTS Nos 1&2	3000A / 3580A	3660A / 4780A
HWTS-ROTS No3	3000A / 3530A	3960A / 4990A

Table 4-1: Existing Conductor and Termination Ratings For Latrobe Valley to Melbourne 500 kV Lines

Under outage conditions, the continuous rating of two 500 kV circuit breakers at HWTS also has the potential to constrain flows to Melbourne. The two circuit breakers are the SMTS No.1 Line / No.2 Bus CB and the SMTS No.2 Line / No.2 Bus CB which are each rated 2500 Amps at 35°C. This constraint is caused by uneven supply into the lines through each of the CB's switching them.

The line termination upgrade has the effect of increasing the overall thermal capability limit between the Latrobe Valley and Melbourne by 1540 MW, to 7400 MW with all transmission lines in service. For line outage conditions, the thermal capability limit increases by 770 MW to 4200 MW. These values are based on ambient temperature conditions of 40°C.

As detailed in the accompanying Economic Evaluation document, the benefits associated with thermal upgrades are calculated from market simulations covering fiscal years from 2002/3 to 2011/12. Potential line loading is calculated based on the market dispatch scenarios derived from the monte carlo market simulations which allows a probabalistic assesment of the need for generation rescheduling or even load shedding to be made. Further details of the impacts of the increased transfer capability are described in Appendix 5.

As a direct consequence of the increased transfer capability, and in addition to reduced exposure to generation constraints and load shedding, the proposed augmentation also:

- Increases the window of opportunity to carry out scheduled maintenance on the 500 kV network, even with future increases in the level of Latrobe Valley 500 kV connected generation; and
- Reduces dependence on the six Latrobe Valley to Rowville 220 kV lines as the need for parallel operation with the 500 kV lines is reduced.

This alternative has no impacts (and therefore provides no benefits or disadvantages) when considering the voltage collapse limit, the transient stability limit, fault current levels or the amount of transmission losses incurred on the network.

The scope of works for Alternative 1, the line termination upgrade includes;

- Replacement of line traps on the three 500 kV lines.
- Replacement of two 500 kV circuit breakers at HWTS which switch the No.1 and No.2 SMTS Lines to the No.2 bus.

The estimated cost of these works is around $2.6M ±12.5%

5) Alternatives 2 and 3: The Rowville or Cranbourne Options

From a shared network perspective, where the focus is on optimising the transfer capacity between the Latrobe Valley and Melbourne, the Rowville or Cranbourne options are very similar.

Each of these alternatives involves conversion of the HWPS-ROTS No.3 220 kV Line to operation at its design voltage level of 500 kV. Effectively, the HWPS-ROTS No.3 Line is removed from service, and it becomes the 4^{th} 500 kV line between the Latrobe Valley (HWTS) and Melbourne (ROTS). The HWPS-JLTS No.2 220 kV Line is also re-instated.

However, with the removal of the HWPS-ROTS No.3 220 kV line, the security of supply to the eastern metropolitan area, at the 220 kV level, is reduced. To compensate, a new 500/220 kV transformer is required in the region. Possible locations for this new transformer are Rowville, Narre Warren and Cranbourne. Locations to the west of Rowville are not considered, as these locations do not provide the necessary security improvements.

Rowville is an established terminal station with one 500/220 kV transformer. Provisions have been made at this station for a second 500/220 kV transformer, and it could be added with two additional 500 kV circuit breakers, some extension of the 500 kV switch yard and line re-arrangements.

Both the Narre Warren and Cranbourne options require establishment of a new “greenfield” terminal station, the costs of which would be similar and greater than those for the Rowville option. As discussed in further detail in Appendix 2, TXU Networks and United Energy have advised of a preference for development at Cranbourne to secure supply to loads out of East Rowville,Tyabb and their planned 220/66 kV terminal station at Cranbourne. The indicative timing of the proposed 220/66 kV works is between summer 2002/03 and 2006/07 and is sensitive to other alternatives such as demand side management and new generation. Narre Warren does not provide the same level of benefits as development at Cranbourne and is not considered further in this assessment.

Aspects of the Cranbourne station development works proposed by TXU Networks and United Energy are common to the Cranbourne option considered for optimising the Latrobe Valley to Melbourne transfer capability. As such, the timing of the 220/66 kV development will influence the costs associated with the 500/220 kV Cranbourne alternative considered in this assessment. The estimated cost of common works is between $8-9M and it would not be appropriate to consider these against the 500/220 kV development if they were already justified by TXU Networks and United Energy.

Additional benefits to be gained by establishing Cranbourne are improved reliability to loads supplied from East Rowville and Tyabb Terminal Stations and further diversity of supply into the Melbourne metropolitan area. However, development at Cranbourne would be subject to environmental and public approval processes that are expected to be more complicated than those for the Rowville option since Rowville is already a well developed site.

VENCorp studies have shown that a third eastern metropolitan area 500/220 transformer is required by around 2005/06 as described in the 2001 Annual Planning Review. If the Cranbourne option is not justified as part of this project, the Cranbourne site may be the preferred option for the third eastern metropolitan transformer.

Common to both the Rowville and Cranbourne options is a need to re-develop the Latrobe Valley network arrangements. Under existing arrangements, the HWPS-ROTS No.3 220 kV line delivers power directly to the ROTS No.1-2 220 kV bus group in Melbourne from the HWPS No.2 bus in the Latrobe Valley. Conversion of this line to operation at 500 kV reduces the security of generation connected to the HWPS No 2 bus. As detailed in Appendix 1, the consequences are a need to close the 220 kV bus tie between the HWPS No1 and 2 buses and re-instate the HWPS-JLTS No.2 220 kV Line.

5.1) Impact on Thermal Limits

A 4th 500 kV line between the Latrobe Valley and Melbourne has the effect of increasing the overall thermal capability limit by 2030 MW to 7890 MW with all transmission lines in service and improving the reliability of the connection. For line outage conditions, the thermal capability limit increases by 1830 MW to 5260 MW. These values are based on ambient temperature conditions of 40°C, and further details of these benefits are described in Appendix 5.

As a direct consequence of the increased transfer capability and reliability, and in addition to reduced exposure to generation constraints and load shedding, the proposed augmentation also:

- Increases the window of opportunity to carry out scheduled maintenance on the 500 kV network, even with future increases in the level of Latrobe Valley 500 kV connected generation;
- Reduces the dependence on the six Latrobe Valley to Rowville 220 kV lines as the need for parallel operation with the 500 kV lines is reduced;
- Reduces the phase angle difference between the Latrobe Valley 500 kV and 220 kV networks and reduces the switching surge caused by changing to and from parallel modes of operation;
- Increases the thermal capability of the 220 kV eastern metropolitan area network because the additional 500/220 kV transformer reduces loading on the 500/220 kV transformer at Rowville and the 500/220 kV and 330/220 kV transformers at South Morang. This increase in transformation capability defers the need for another 500/220 kV transformer in the eastern metropolitan area by about two years to 2006; and
- Marginally increases the HWPS 500/220 kV transformation capability by about 35 MW due to proposed bus arrangements at HWPS.

5.2) Impact on Transmission Network Losses

The losses incurred on the transmission network between the Latrobe Valley and Melbourne are significantly reduced by the conversion of the HWTS-ROTS No.3 Line to operation at 500 kV. The annual transmission loss reduction for the year 2003/04 is predicted to be approximately 90 GWh (>10.2 MW on average) with the service of the 4th 500 kV line.

The annual transmission loss reduction is about 98 GWh (>11.1 MW on average) with the new 500/220 kV transformer installed at Cranbourne as opposed to Rowville.

The level of transmission losses is directly related to the amount of generation injected into the 500 kV network in the Latrobe Valley area. As this generation injection is relatively constant due to the base-load nature of a large proportion of the Latrobe Valley generation, so to is the change in the transmission losses between the Latrobe Valley and Melbourne as Victorian demand changes.

With the 4th 500 kV line, any additional generation connected to the 500 kV network in the Latrobe Valley will be connected to a system that is more efficient from a loss perspective, so increased generation will have the effect of increasing the benefits of this augmentation alternative. Potential loads in the Latrobe Valley, such as BassLink when exporting to Tasmania, will reduce the expected benefits.

5.3) Impact on Fault Current Levels

Fault levels will generally increase following conversion of the 4th line to operation at 500 kV due to the lower impedance of the connection between the Latrobe Valley generation and connection points.

While the increase in fault levels at most metropolitan terminal stations is relatively small, the fault current increase at the Rowville 220 kV bus is significant if the Rowville transformer option is adopted, and the four East Rowville line circuit breakers at Rowville will need to be replaced with 40kA units. There are also increases in fault levels with the Cranbourne transformer option, however the increases can be managed with existing operational arrangements, and no circuit breaker replacement would be necessary.

Fault levels in the Latrobe Valley will also be affected by the proposed closing of bus-ties at HWPS. Independent of the new transformer location, four HWPS 220 kV circuit breakers must be replaced with 50 kA units to maintain rupture capabilities above the expected fault current levels.

5.4) Impact on Voltage Collapse Limits

Loss of the existing HWTS-ROTS 500 kV line is one of the critical contingencies for voltage collapse in Victorian system. With the upgrade of the HWTS-ROTS No 3 Line to operation at 500 kV, an outage on the 500 kV network from Latrobe Valley to Melbourne area will no longer impose a voltage collapse limit.

In addition to the removal of a mechanism of voltage collapse, the Rowville and Cranbourne alternatives reduce the amount of shunt capacitors required to support the summer peak demand by about 350 MVAr by summer 2003/04. This effectively defers the need for new shunt capacitors, which are becoming increasingly expensive as there are no longer simple sites to accommodate new plant.

The increased 500 kV power transfer capability due to higher voltage stability limits are detailed in Appendix 5 and the benefits of deferral of shunt capacitor installations are detailed in Appendix 4.

5.5) Impact on Transient Stability Limits

Victoria's export capability to the Snowy\NSW and South Australian regions is determined by a fault on the HWTS-SMTS 500 kV lines. With either the Rowville or Cranbourne alternative, the critical fault location changes from the HWTS-SMTS 500 kV Lines to the SMTS-DDTS 330 kV Lines. The effective increase in the export capability is about 70 MW.

5.6) Scope of Work and Cost Estimates

The scope of works for Alternative 2, the Rowville option includes;

- Removal of the existing HWPS-ROTS No.3 220 kV line from service, and conversion of the HWTS-ROTS section of the line (500 kV construction) to form a new 500 kV circuit between the Latrobe Valley and Melbourne, as shown in Figure 6. The HWTS end of line will be connected to the HWTS buses using existing 500 kV switchgear, and the ROTS end of the line will be connected to the ROTS buses with two new 500 kV circuit breakers.

- Installation of a new 500/220 kV 1000 MVA transformer at ROTS. The 220 kV side of the new transformer will be connected to ROTS using the former connections and circuit breakers of the HWPS-ROTS No.3 when operating at 220 kV.

- Replacement of four circuit breakers at ROTS on the East Rowville lines to ensure acceptable fault current margins are maintained.

- Re-instatement of the HWPS-JLTS No.2 220 kV Line and re-arrangement of the HWPS busses and consequential replacement of four circuit breakers at HWPS to ensure acceptable fault current margins are maintained.

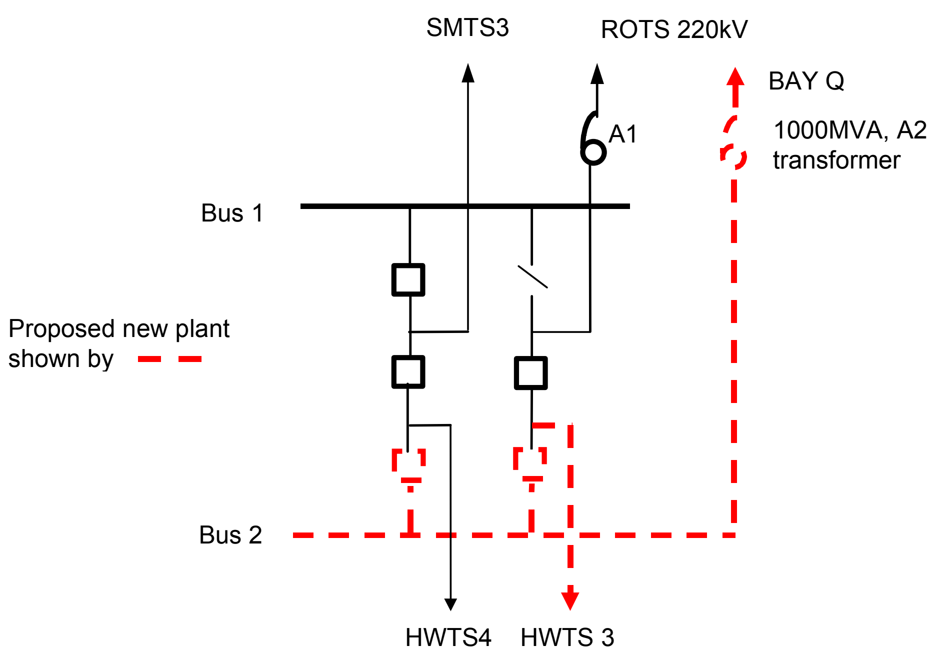

Figure 6: Rowville 500 kV Terminal Station Switchyard modifications

The development cost estimates for the Rowville option (±12.5%) are shown in Table 5-1.

Works	Costs $M
HWPS and HWTS end works, described in Appendix 3	2.15
ROTS end including the transformer, 500 kV works and 220 kV connections	20.14
ROTS 220 kV switchyard	1.47
Total	23.76

Table 5-1: ROTS 500/220 kV transformer and associated works

The scope of works for Alternative 3, the Cranbourne option includes;

- Removal of the existing HWPS-ROTS No.3 220 kV line from service, and conversion of the HWTS-ROTS section of the line (500 kV construction) to form a new 500 kV circuit between the Latrobe Valley and Melbourne. The HWTS end of line will be connected to the HWTS buses using existing 500 kV switchgear, and the ROTS end of the line will be connected to the ROTS buses with one new 500 kV circuit breaker.

- Establishment of Cranbourne 500 kV and 220 kV switch yards with one 500/220 kV 1000 MVA transformer. The 500 kV supply to Cranbourne will be formed by cutting into the new HWTS-ROTS No3 500 kV line and the East Rowville-Tyabb 220 kV lines will be switched into to form the 220 kV demand side of the yard.

- Re-instatement of the HWPS-JLTS No.2 220 kV Line and re-arrangement of the HWPS busses and consequential replacement of four circuit breakers at HWPS to ensure acceptable fault current margins are maintained.

Two switching arrangements have been developed for the Cranbourne 220 kV switchyard;
Alternative 4A, the Cranbourne 220 kV switching arrangement shown in

- Figure 7 that provides a more secure arrangement for the 220 kV connections back to Rowville.

- Alternative 4B, which is another configuration as shown in Figure 8, which has less circuit breakers in the Cranbourne 220 kV switchyard but requires an additional circuit breaker in the existing Tyabb 220 kV switchyard.

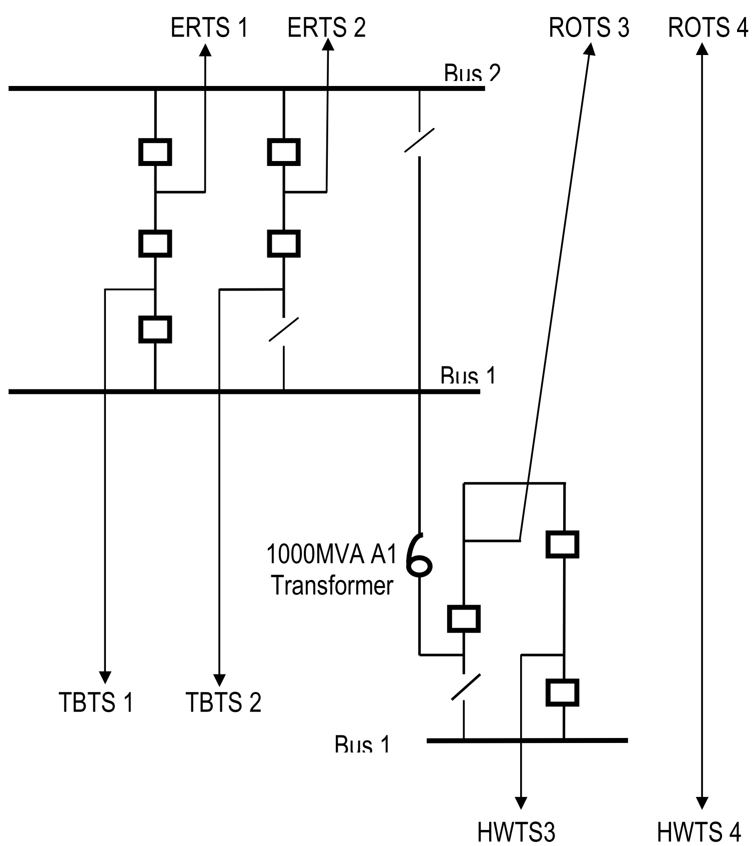

Figure 7: Alternative 4A Cranbourne 500 kV and 220 kV Switch yard arrangements.

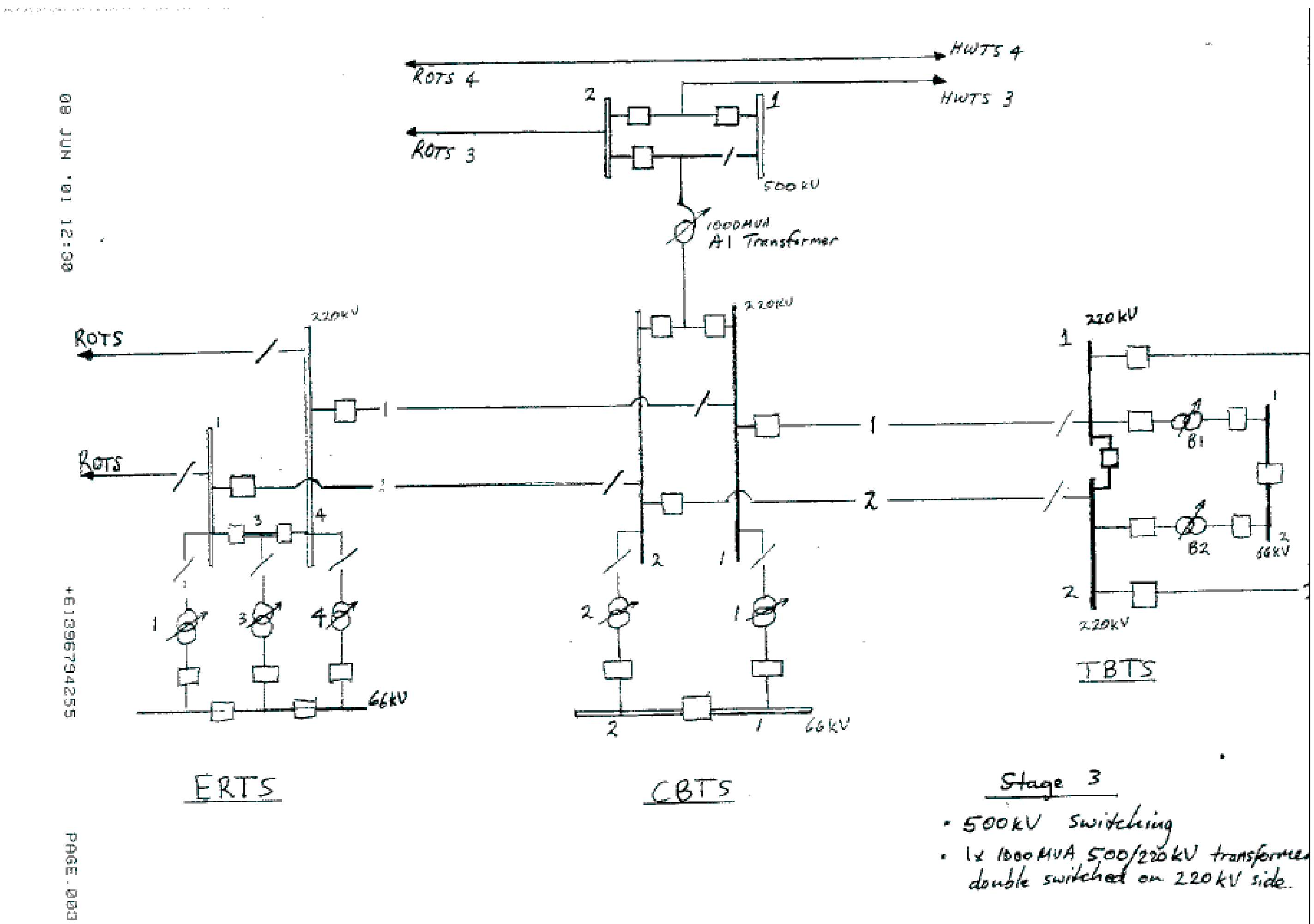

Figure 8: Alternative 4B Cranbourne 500 kV and 220 kV Switch yard arrangements

The costs of establishing the Cranbourne terminal station with a 500/220 kV 1000 MVA transformer are shown in Table 5-2 for the two switching arrangements described. Works at the Rowville end and at the Hazelwood end have been included and the cost estimates are based on ± 12.5% accuracy.

Development works	Cranbourne Alternative 4A Costs $M	Cranbourne Alternative 4B Costs $M
Cranbourne and ROTS 500 kV works	33.7	36.0
HWTS and HWPS works	2.15	2.15
Total	35.85	38.15

Table 5-2: Development costs for establishment of a 500/220 kV station at Cranbourne

6) Alternative 4: The Fifth 500 kV Line Option

This option involves building a new 500 kV line from the Latrobe Valley to Melbourne. This new line would be built in the existing northern easement from HWTS to Templestowe via Coldstream. This line would be switched to the existing ROTS-South Morang 500 kV line at a new 500 kV switchyard developed at Templestowe, utilising an existing section of 500 kV line as shown in Figure 9. The proposed switching arrangement as Templestowe is shown in Figure 10

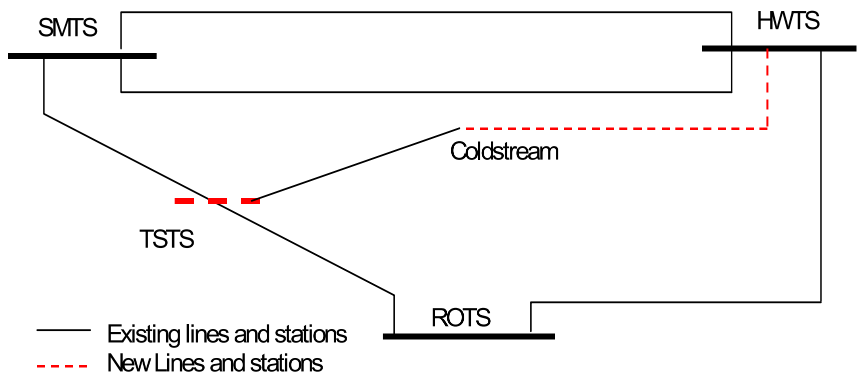

Figure 9: Latrobe Valley to Melbourne 500 kV network

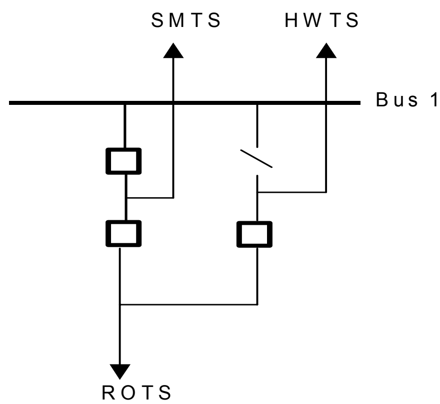

Figure 10: Proposed TSTS switching arrangement

Development of a 5th 500 kV line would be subject to environmental and public approval processes for construction of the new line and establishment of a 500 kV switchyard at Templestowe.

6.1) Impact on Thermal Limits

The 5th 500 kV line increases the thermal capability limit of the 500 kV transmission network between Latrobe Valley and Melbourne by 2630 MW to a new limit of 8500 MW with all transmission lines in service. The thermal capability limit increases by 2630 MW to a new limit of 6060 MW with one 500 kV line out of service. These values have been calculated at 40°C ambient temperature conditions and further details of the benefits to be achieved with this alternative are described in Appendix 5.

There are no additional 500/220 kV transformers in this project and therefore, no change to the metropolitan area 500/220 kV transformation capacity.

6.2) Impact on Transmission Network Losses

The losses incurred on the transmission network between the Latrobe Valley and Melbourne are significantly reduced by with the construction of a new 500 kV line. The annual transmission loss reduction for the year 2003/04 is predicted to be approximately 92 GWh (>10.5 MW on average).

The level of transmission losses is directly related to the amount of generation injected into the 500 kV network in the Latrobe Valley area. As this generation injection is relatively constant due to the base-load nature of a large proportion of the Latrobe Valley generation, so to is the change in the transmission losses between the Latrobe Valley and Melbourne as Victorian demand changes.

With a 5th 500 kV line, any additional generation connected to the 500 kV network in the Latrobe Valley will be connected to a system that is more efficient from a loss perspective, so increased generation will have the effect of increasing the benefits of this augmentation alternative. Potential loads in the Latrobe Valley, such as BassLink when exporting to Tasmania, will reduce the expected benefits.

6.3) Impact on Fault Current Levels

Fault current levels will generally increase with construction of a 5th 500 kV line, however the increase is not excessive and operating action will be sufficient to maintain fault currents within the circuit breaker interrupting capabilities.

There is no proposed change to the HWPS bus arrangement with the 5th 500 kV line option.

6.4) Impact on Voltage Collapse Limits

Loss of the existing HWTS to ROTS 500 kV line is one of the critical contingencies for voltage collapse in Victorian system. With the upgrade of the HWTS-ROTS No 3 Line to operation at 500 kV, an outage on the 500 kV network from Latrobe Valley to Melbourne area will no longer impose a voltage collapse limit.

In addition to the removal of a mechanism of voltage collapse, the 5th 500 kV line alternative will reduce the amount of shunt capacitors required to support the summer peak demand by about 400 MVAr by summer 2003/04. This effectively defers the need for new shunt capacitors, which are becoming increasingly expensive as there are no longer simple sites to accommodate new plant.

The increased 500 kV power transfer capability due to higher voltage stability limits are detailed in Appendix 5 and the benefits of deferral of shunt capacitor installations are detailed in Appendix 6.

6.5) Impact on Transient Stability Limits

Victoria's export capability to the Snowy\NSW and South Australian regions is determined by a fault on the HWTS-SMTS 500 kV lines. With either the Rowville or Cranbourne alternative, the critical fault location changes from the HWTS-SMTS 500 kV Lines to the SMTS-DDTS 330 kV Lines. The effective increase in the export capability is about 100 MW.

6.6) Scope of Work and Cost Estimates

The scope of works for Alternative 4, the 5th 500 kV Line option includes;

- An additional single switched 500 kV bay at Hazelwood Terminal Station;
- A new 110km single circuit quad orange with ground wire 500 kV line section to Coldstream;
- Re-instatement of the existing Coldstream - Templestowe 500 kV line section; and
- Establishment of a 500 kV switchyard at Templestowe to tee into the existing SMTS-ROTS 500 kV Line based on a ring arrangement using three 500 kV CB's.

The estimated cost of line works and switching is around \$71 M $\pm$ 12.5%

7) Non-Network Alternatives

Non-network alternatives can be considered by reviewing the areas of benefit achieved with the network solution:

- *Reduction in the Latrobe Valley generation which causes generation rescheduling*
  To achieve this, base load generation to the west of the Latrobe Valley to Melbourne corridor with short run marginal costs lower than the existing brown coal generation would be required and this is impractical and would be uneconomic from a capital cost viewpoint. DSM would be uncompetitive at $ 300/MWh.

- *Reduction in the Latrobe Valley generation which causes load shedding (or Expected Unserved Energy, EUE)*
  DSM and peaking plant to the west of the Latrobe Valley to Melbourne corridor would achieve the same benefit.

- *Shunt Capacitor Deferment*
  DSM and peaking plant to the west of the Latrobe Valley to Melbourne corridor would achieve the same benefit

- *Reduction of Transmission Network Losses* -
  To achieve this, base load generation to the west of the Latrobe Valley to Melbourne corridor with short run marginal costs lower than the existing brown coal generation would be required and this is impractical and would be uneconomic from a capital cost viewpoint.

The above review suggests that there are no economic competitors for the network solution, however certain market development scenarios may affect the benefits seen for the network solution. Generation and DSM alternatives are not considered as direct solutions for this project, but their effect on the proposed network solutions is considered by including them among the market development scenarios as discussed in the accompanying Economic Assessment document.

7.1) Demand side management

Demand side management (DSM) could be used to reduce the amount of energy at risk of shedding due to the transmission constraint and reduce the amount of reactive support required for supporting the peak demand. It is not expected to be a cost-effective alternative to the generation re-scheduling that is required due to the transmission constraint. The impact of DSM has been investigated as a market development scenario in the economic evaluation.

7.2) Generation alternatives

The market scenarios to be considered that may impact on the benefits from the transmission alternatives are;

- Development of the SNOVIC 800 MW option. This represents a 400 MW generation increase on the Melbourne side of the line.

- Retirement of 500 MW of Latrobe Valley brown coal generation. Retired generation to be replaced by gas fired generation in Victoria of which 50% considered to be connected to Melbourne metropolitan area and the rest to Latrobe Valley.

- Changed bidding strategy from a Short Run Marginal Cost (SRMC) to a Long Run Marginal Cost (LRMC) bidding strategy. This bidding strategy increases import from Snowy to Victoria to the maximum limit and offset Latrobe Valley base load generation considerably reducing flow on the 500 kV lines from Latrobe Valley to Melbourne. This is equivalent to a 1900 MW base load generator being connected to Melbourne area and offsetting Latrobe Valley generation

8) Comparison of Alternatives

Depending on the alternative considered, the benefits of strengthening the 500 kV transmission network between the Latrobe Valley and the Melbourne metropolitan area can include:

- a reduction in losses on the transmission system;
- a reduction in the potential amount of generation re-scheduling necessary under line outage conditions due to the Latrobe Valley to Melbourne thermal capability;
- a reduction in the potential amount of expected unserved energy (load shedding) necessary under line outage conditions due to the Latrobe Valley to Melbourne thermal capability; and
- a reduction in reactive losses during the summer peak demand.

The full cost benefit assessment of each alternative is carried out in the accompanying Economic Evaluation document however a summary is provided in Table 8-1:

Alternative	Reduction in generation rescheduling	Reduction in Unserved Energy	Reduction in transmission losses	Reduction in reactive losses	Relative Cost
Termination upgrade	Yes	Yes	No	No	Low
Rowville option	Yes	Yes	Yes	Yes	Average
Cranbourne option	Yes	Yes	Yes	Yes	Average
5th 500 kV line	Yes	Yes	Yes	Yes	High
DSM	No (Uncompetitive as SRMC costs higher than brown coal)	Yes	No	Yes	High
Additional generation	Yes (but uncompetitive as SRMC costs higher than brown coal)	Yes	Yes (Reduce as generators close to the load centre)	Yes	High

Table 8-1: Comparison of benefits provided by alternative projects

APPENDIX 1

Rowville and Cranbourne Options – Latrobe Valley Works

Under system normal operating conditions, the operating arrangement in the Latrobe Valley is known as ‘radial mode’. This is shown in Figure A1-1. Radial mode is the preferred arrangement as it ensures the highest loading on the 500 kV Latrobe Valley to Melbourne network while reducing loading on the 220 kV Latrobe Valley to Melbourne network. This ensure power losses are minimised while the security of the 220 kV network is maximised as under other ‘parallel’ modes these lines could be overloaded during outage conditions at times of high ambient temperatures.

In radial mode, three of the eight HWPS generators (G3-5) feed into the transmission network via two paths. The first path is via the HWPS-ROTS No.3 Line (which is the 500 kV line operating at 220 kV) and the second path is via the 220/500 kV A1 transformer at HWTS and then through the three existing 500 kV transmission lines. The proposed conversion of the HWPS-ROTS No.3 line to operation at 500 kV has the consequence of providing an insecure connection for these three generators. This is considered unacceptable, so re-arrangement of the connections is required should the HWPS-ROTS No.3 line be upgraded to operation at 500 kV.

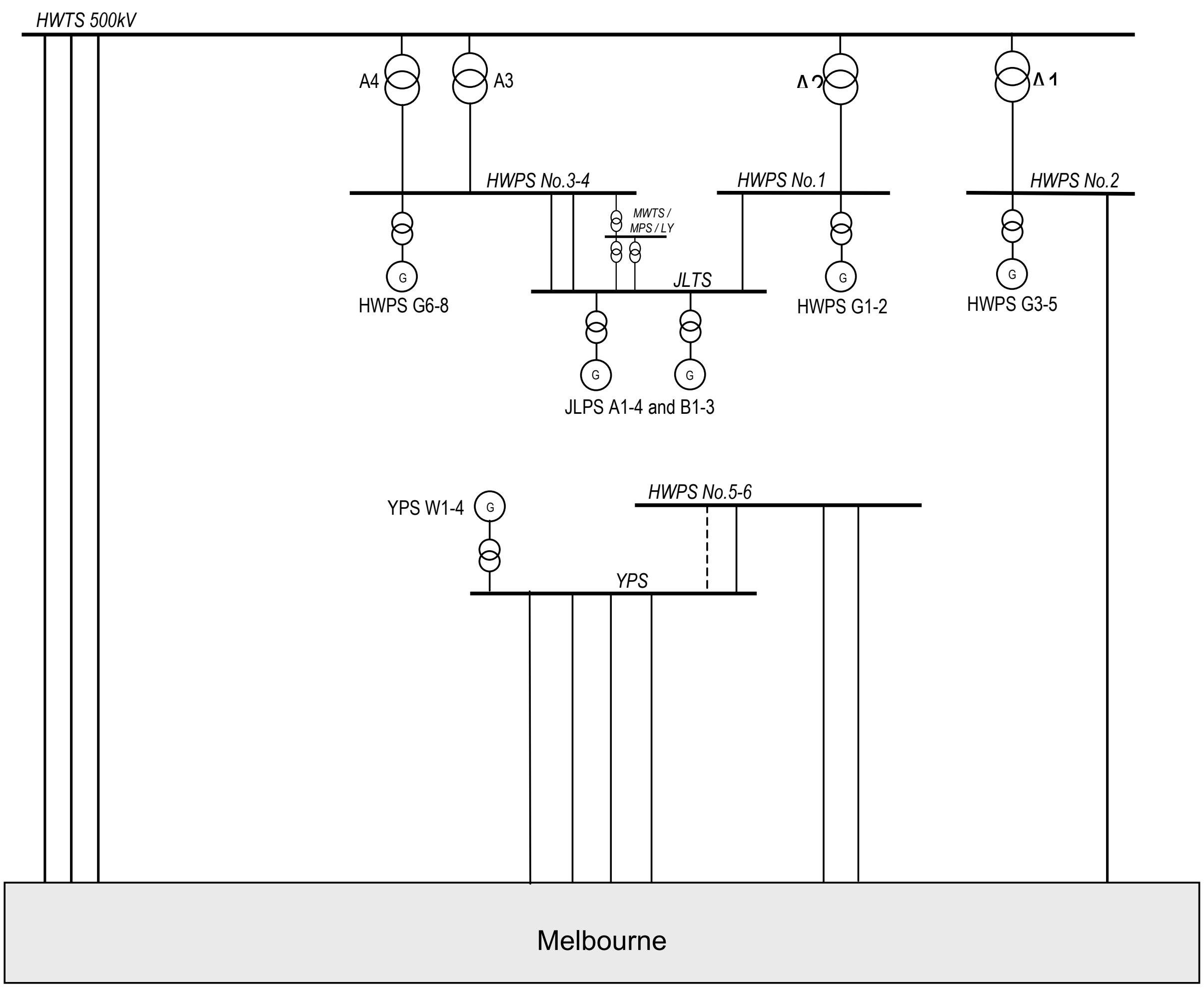

Figure A1-1: Existing Latrobe Valley to Melbourne network configuration.

The proposed Latrobe Valley operating arrangement following service of the 4th 500 kV line is shown in Figure A1-2

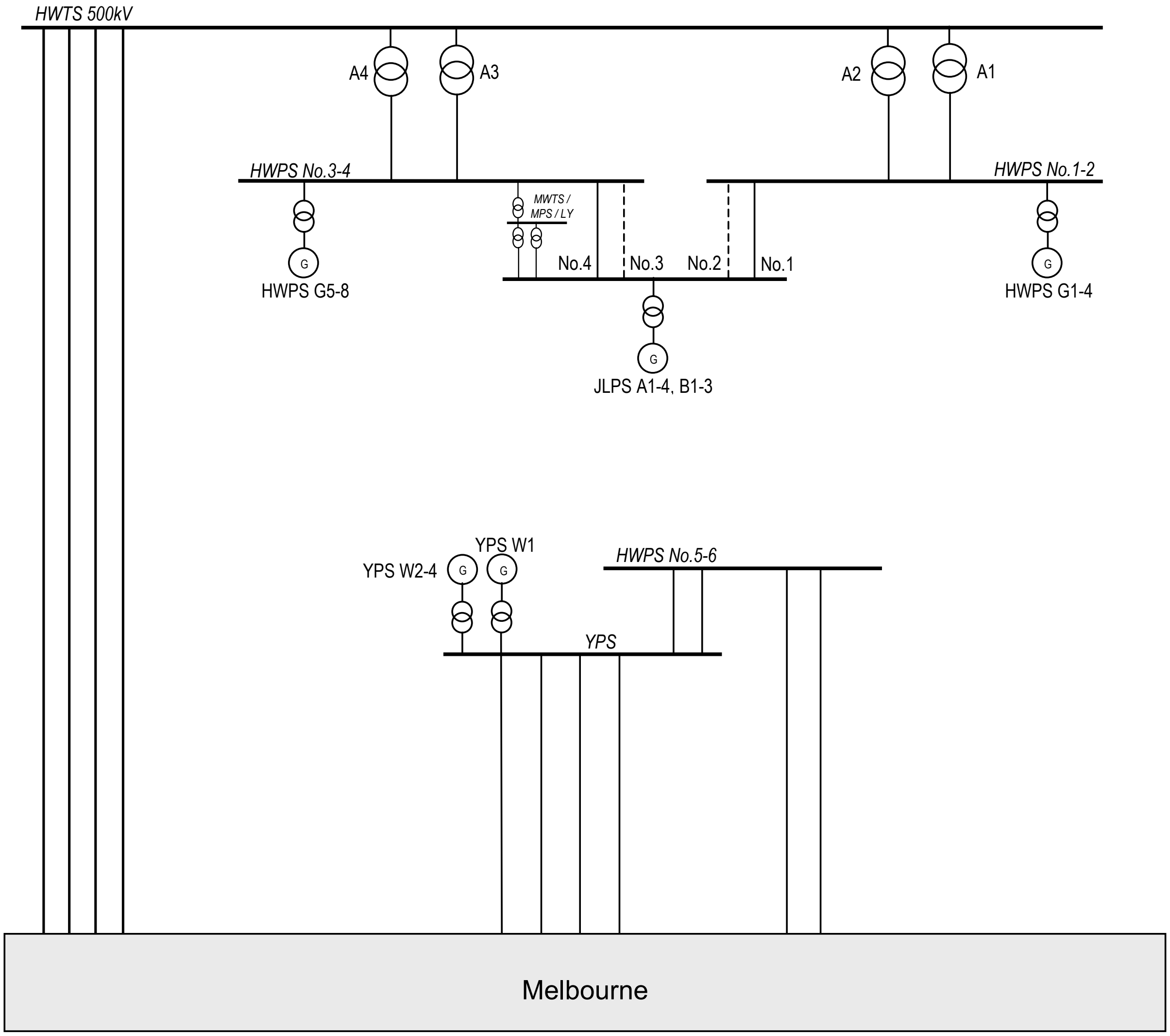

Figure A1-2: Proposed Latrobe Valley to Melbourne network configuration after the HWPS-ROTS No.3 line is upgraded to operation at 500 kV.

The No 1,2,3 & 4 buses at HWPS will be arranged into two groups, Bus group 1-2 and Bus group 3-4 which will each have four Hazelwood Power Station generators directly connected to them. The generators are arranged so that no more than two generators are disconnected following any single bus outage. Each of these bus groups will be connected to the 500 kV network via two HWTS 220/500 kV transformers and to each other via the four HWPS-JLTS lines. Under system normal conditions it is proposed that two of the four lines from HWPS to JLTS will be left open to ensure that fault levels remain at acceptable levels.

The HWPS bus group 5-6 remains dedicated to the Yallourn 220 kV system and remains electrically isolated from the Latrobe Valley 500 kV system under system normal conditions.

The design provides for a robust, symmetrical arrangement without the need for extensive augmentation and the associated high costs.

2.2 Fault levels

With the proposed arrangement it will be necessary to replace selected switchgear at HWPS. The fault level at Hazelwood Power Station Bus Group 1&2 will be within the capability of all CBs connected to the bus, however four 220 kV CBs will require replacement at the Bus 3&4 group. The circuit breakers requiring replacement are the MPS-MWTS/No.4 bus CB, the G5 / No.4 bus CB, the G6 / No.4 CB bus and the G8 / No.4 bus CB which need to be upgraded to 50kA units

Existing arrangements at HWPS and Yallourn Power Station (YPS) allow for one of the four Yallourn generators to be switched from the 220 kV network into the 500 kV network, provided that certain conditions relating to fault levels, thermal loading of the HWTS transformers and reactive support capability are met. The proposed arrangements after conversion of the HWPS-ROTS No.3 line to operation at 500 kV will be slightly less restrictive than at present.

With the present Latrobe Valley network configuration, the effects of 500 kV line outages are minimised by operating the system in a parallel mode. This strategy increases utilisation of the 220 kV transmission lines and therefore can only be used when the thermal capacity of these lines is adequate, i.e. at low to moderate ambient temperatures and/or with low Yallourn generation. With the proposed Latrobe Valley network configuration, there will still be three 500 kV lines in service even when one is taken out for maintenance so the proposed arrangement virtually eliminates the need to transfer the system into a parallel mode for 500 kV line outages.

Under the proposed arrangements, planned outages of one of the HWTS A1 – A4 transformers will most likely result in the system operating in a satisfactory state however it will not be secure. Security can be achieved by coordinating planned outages at times when the aggregated generation feeding the transformers is reduced by at least 600 MVA from installed capacity (i.e. Jeeralang plus at least one HWPS unit off-line). This should give a sufficient window off opportunity for the required annual maintenance. The normally open HWPS-JLTS lines may need to be closed to provide a bus group tie of sufficient thermal capability depending on the generation scenarios realised.

The total costs for the works at the Latrobe Valley end are estimated to be \$2.15M $\pm$12.5% and include replacement of 4 x 220 kV circuit breakers and line and line connection works.

Appendix 2

Additional Reliability Benefits of the Cranbourne Option

In addition to reducing energy at risk on the 500 kV network and lowering the active and reactive power losses, the connection at Cranbourne would also provide an increase in reliability of supply to East Rowville and Tyabb electricity supply. This benefit has been included in the economic assessment. The changes to the reliability of supply to ERTS and TBTS assessment are described in this section.

The double circuit tower line ROTS-ERTS-TBTS was constructed in the 1970's to supply the ERTS and TBTS areas.

According to historical line outage records, the total outage duration of one of these lines is 1.54 hrs per year and no tower failures have been recorded since installation. This level of reliability has been considered adequate for the ERTS and TBTS area. However, this outage sample of the ROTS-ERTS-TBTS lines may be too small to predict long term reliability of supply so therefore, VENCorp has used reliability figures including the performance of other similar lines in the Victorian transmission system.

In making this assessment the following assumptions have been made:

- The Victorian line design code was reviewed around the mid 1960's and as a result lines that have been built after mid 1960's are considered stronger than the old lines. Therefore lines constructed before and after mid 1960's are separated for failure analysis involving tower design.
- The 500 kV, 330 kV, and 220 kV lines could be combined for tower failure analysis.
- There is no difference between single circuit towers and double circuit towers for tower failures due to wind
- For bush fires, both single circuit tower line outages and double circuit tower line outages have been included independent of the construction time.

Using this broader base, forced outage rates per 100 km per year, based on historical outage data are obtained as shown in Table A2-1:

Type	Duration (hr)	Number of incidents	Average Duration per Incident (hrs)	Probability
Single circuit	13.87	1.12	12.36	0.001583
Double circuit	0.3440	0.0371	9.2695	0.000039

Table A2-1: Actual circuit forced outage rates per 100 km per year

With double circuit lines, apart from events that effect both circuits, such as a tower failure, there can also be the coincident outage of both circuits for "independent" events. If these were truly independent events then the double circuit outage probabilities could be obtained by squaring the single circuit outage probabilities. This method is not considered as a true reflection of double circuit outage levels as there is a high probability that these events are not truly independent and the second event is precipitated by the first event. This has been tested using the actual outage data.

Based on this analysis the double circuit outage levels can be obtained from the single circuit outage levels by squaring the single circuit outage probability and multiplying by 16, for a 100km line length.

Based on the historical performance of similar transmission lines in Victoria estimated outage levels of ROTS-ERTS-TBTS lines are described in Table A2-2;

Transmission line	**Service date**	**Length (km)**	**Outage probability (duration / 8750)**	
			Single circuit	**Double circuit**
ROTS-ERTS	1970	1.85	0.000029	7.48E-07
ERTS-TBTS	1977	41.5	0.000657	1.68E-05
ERTS-CBTS	1977	19.3	0.000306	7.8E-06

Table A2-2: Estimated outage levels of ROTS-ERTS-TBTS lines

Actual performance of ROTS-ERTS-TBTS lines is much better than these levels;

- Actual single circuit total outage duration of these lines is 1.54 hrs per year and the above reliability levels result in 12 hrs outage duration per year. This is an increase by a factor of about 8 times.

- No tower failures have been recorded for the ROTS-ERTS-TBTS lines or for 220 kV lines constructed after mid 1960's and the above reliability levels result in 0.3 hours tower outage duration per year.

Additional reliability benefits gained by establishing the Cranbourne option as opposed to the Rowville option, based on the reliability indices shown in Table A2-2, are shown in the Table A3-3 for the study period:

Financial Year Ending	Expected Unserved Energy (EUE) at ERTS and TBTS	
	MWhr	$M
2002	31.00	0.31
2003	32.41	0.32
2004	34.01	0.34
2005	35.84	0.36
2006	38.25	0.38
2007	41.15	0.41
2008	45.01	0.45
2009	49.53	0.50
2010	55.18	0.55
2011	61.90	0.62
2012	69.52	0.70

Table A3-3: Additional benefits of establishing Cranbourne

These values are based on ERTS and TBTS terminal station load forecast compiled by VENCorp in September 2001 with input from the relevant distribution businesses and valued using price of VoLL ($10,000 per MWhr).

Appendix 3

Network Performance Standards

In assessing the adequacy of the existing network and the impact of the alternative augmentation options, the following planning criteria have been used. Many of these are described as the network performance standards in schedule 5.1 of the National Electricity Code.

Design criteria and assumptions

A detailed description of VENCorp's transmission planning criteria is shown in Appendix A2 of VENCorp's 2001 *Electricity Annual Planning Review*. In summary, in order to maintain a secure system, the design principles and approach used by VENCorp for planning the transmission network are as follows:

- The system must be able to sustain any single outage, including disconnection of any single generator, busbar or transmission element, and remain within performance limits as defined in the National Electricity Code. For purposes of calculating inter-regional transfer capabilities, busbar faults are not included.

- Following the forced outage of a single network element, it must be possible to 're-adjust' the system within 30 minutes so that it is capable of tolerating a further forced outage without risk to the security of the overall network. This may involve network switching and/or modification to generation dispatch to account for the new system constraints. Blocks of load may be at risk of disconnection either directly by a second failure (such as for loads that are supplied by two lines where the first line is unavailable and the second line fails) or by load shedding action to ensure that the system is capable of remaining in a secure state if the second event occurs.

- Adequate control measures are in place to secure the power system (ie. retain the system in a stable and controllable condition) and minimise the extent of disruption to customers following low probability events not catered for by the basic network design.

- Sufficient periods are available to allow maintenance of critical shared network elements without exposing the network to excessive risk in the event of a further unscheduled outage of a network element. These parts of the network must have sufficient capacity to reliably meet transfer requirements with two elements out of service during light load when maintenance is scheduled.

Two main criteria apply when determining plant sizing and transfer limits. These are summarised as follows:

Voltage Limits

Voltage changes as a result of plant switching, such as capacitor bank or reactor switching are limited to:

- 3% on all buses under normal conditions. This is a limit imposed by AS/NZS 61000.3.7 for step changes less than one per hour.

Voltage changes as a result of contingent events such as line or transformer trips are limited to:

- 10% on all buses 66 kV and above for short-term effects, ie before transformer tapping and reactive plant switching.
- 5% on 66 kV and 10% on 220 kV and higher for long term solution, ie after transformer tapping and reactive plant switching.
- Generally voltage to be maintained within +/- 10% of nominal unless special local conditions apply.

Thermal Limits

Thermal limits on lines are maintained within continuous rating during normal conditions. For contingent events such as line or transformer trips, the following thermal limits apply:

- Loading to be within short time ratings for short term solutions, ie before transformer tapping and after reactive plant switching. Short term ratings may be 5 minute, 15 minute or 20 minute depending on the plant being overloaded and the degree of Network Control Ancillary Service (NCAS) available. For 5 minute ratings, automatic control action is required to offload the network elements as manual intervention by operators is not expected in this time interval.
- Loading to be within long term or continuous ratings for long term solutions, ie after all transformer tapping and reactive plant switching. This includes 30 minute ratings, as generation rescheduling will be undertaken by NEMMCO to restore loading within continuous limits.

Cost estimates

A number of capital cost estimates are provided in this report. It is emphasised that cost estimates are preliminary and indicative only (that is, in the order of +/- 12.5%) and exclude GST. Cost estimates for augmentation options were obtained from the following sources:

- SPI PowerNet;
- VENCorp estimates based on the costs of recently completed transmission augmentation projects in Victoria.

Appendix 4

Deferral of Shunt Capacitors

The Rowville option, the Cranbourne option and the 5th 500 kV line transmission option each provide an increase in the reactive capability of the network. The increase in the reactive capability avoids the need for shunt capacitors which otherwise would have been installed to support the summer peak demand. The amount of shunt capacitors deferred in each year of analysis is summarised in the Table A4-1 and Table A4-2.

Financial year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	
Benefits											
Reduction in:											
Shunt capacitors MVAr	335	350.00	370.00	390.00	410.00	430.00	450.00	470.00	490.00	510.00	
Shunt capacitors $M	0.75	0.79	0.83	0.88	0.92	0.97	1.01	1.06	1.10	1.15	

Table A4-1: 4th 500 kV Line - Rowville and Cranbourne Options

Financial year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	
Benefits											
Reduction in:											
Shunt capacitors MVAr	385	400	420	440	460	480	500	520	540	560	
Shunt capacitors $M	0.87	0.90	0.95	0.99	1.04	1.08	1.13	1.17	1.22	1.26	

Table A4-2: 5th 500 kV Line

The value of avoided shunt capacitors is $2,250 per MVAr per year

APPENDIX 5

Latrobe Valley to Melbourne Transmission Constraints, Overloading Assessment and Line Performance

This Appendix aims to outline the methodology used to determine the transmission constraints under line outage conditions and show how the amount of generation to be rescheduled or the amount of load shedding required is identified.

In accordance with the National Electricity Code (NEC), following an unplanned outage of a transmission element, it must be possible to re-configure the power system within 30 minutes to sustain the next critical single forced outage and while still remaining in the satisfactory operating state. This is achieved by determining the first limiting transmission constraint with the two most critical elements out of service and then estimating the amount of energy transported above this transmission capability limit.

The transmission constraints are formulated such that the system would remain in a satisfactory condition following contingent loss of a second Latrobe Valley (LV) to Melbourne 500 kV line, which would be the next most single credible critical contingency.

Any constraints on the Latrobe Valley to Melbourne 500 kV transmission network can limit the total output of the following group of generators connected to the 500 kV system:

Hazelwood	(HWPS)	1600
Loy Yang A & B	(LYPSA&B)	3000
Jeeralang A & B	(JLGSA&B)	460
Morwell	(MPS)	170
Bairnsdale	(BPS)	80
Valley Power	(VP)	300
Total Existing Generation		5610 MW

Thermal Constraints

Thermal constraints relate to limiting flow on the critically loaded transmission circuit to within thermal or line protection limits.

The critical outage for the transmission network from Latrobe Valley to Melbourne is either a HWTS-SMTS or HWTS-ROTS 500 kV line. In each case, the subsequent worst case contingency for which the system must be secured is that which results in a single HWTS-SMTS line remaining in service. System capability is therefore equivalent for either prior outage. The remaining HWTS-SMTS line is the critically loaded circuit for determining line flow related constraints.

The following equation defines the thermal ratings applicable for each alternative considered at any ambient temperature given the 35°C and 5°C thermal ratings listed in Table A5-1

$S(t) = (((t-5)*S_{35}^2 + (35-t)*S_5^2)/30)^{1/2}$

where: S_{35}= MVA = rating at 35°C and 1pu voltage

S_5= MVA = rating at 5°C and 1pu voltage

t = ambient temperature

Development Options	Rating (MVA)	
	S_5	S_{35}
Do nothing	3100	2600
Termination upgrade	4150	3400
Rowville option	6200	5200
Cranbourne option	6200	5200
5th 500 kV line option	93003	78004

Table A5-1: The Latrobe valley thermal transfer capability at 35°C and 5°C

No short-term ratings are assumed for the line terminations.

Unserved energy associated with the above line flow ratings is to be derived from hourly market simulation data using linearised line flow equations. These equations define the Latrobe Valley to Melbourne transfer levels based on Latrobe Valley generation levels

S = A * (LYPSA&B+JLGSA&B+MPS+HWPS12678MW+LYGT+Basslink (Tas→Vic)+Bairnsdale)
+ B * (HWPS345MW)
+ C * P_{vic}
+ D

Where: S =Line loading calculated as MVA at 1pu voltage
P_{vic} =Victorian demand
$C.P_{vic}$ represents effect of Morwell load on line flow

Values for the constants A, B, C and D are shown in Table A5-2.

Development Options	A	B	C	D
Do nothing	0.85	0.67	-0.03	-670
Termination upgrade	0.85	0.67	-0.03	-670
Rowville option	1	1	-0.03	-684
Cranbourne option	1	1	-0.03	-684
5th 500 kV	0.94	0.68	-0.03	-300

Table A5-2: Coefficients for line flow equation

Reactive Constraints

Reactive constraints are defined to provide acceptable post contingent dynamic voltage recovery and subsequent steady state reactive margins.

The following voltage recovery criterion is applied after loss of the second 500 kV circuit:

- Post contingent voltage on all 220 kV busbars to be above 90% within 200ms of initiation of the 500 kV line trip.

This criterion is based on preventing stalling of induction motor / air conditioning loads. These loads, which are assumed not to stall at the voltages simulated, are modelled with summer power factor and a voltage dependent load characteristic Np=1, Nq=2.

The following criterion is applied relating to steady state reactive margin:

- Reactive margin to equal or exceed that corresponding to 1/100 times the reciprocal of the system normal fault admittance at the critical system busbar. For these studies this corresponds to a margin of approximately 150 MVAr on the SMTS 500 kV bus.

Steady state reactive margin with prior outage of a Latrobe Valley – Melbourne 500 kV line and loss of a second line is defined as follows:

- After initial loss of the first 500 kV line, sufficient shunt banks are placed in service to maintain dynamic reactive plant between zero output and approximately 30% absorption. This ensures a reasonable voltage profile and secures against overvoltages, which may otherwise occur for loss of load.

- Immediately after subsequent loss of the second line and before any automatic switching of shunt banks, a load characteristic Np=1, Nq=2 is assumed.

- The final reactive margin is assessed with all available EHV cap banks switched in and loads represented at their precontingent values with a constant MVA load characteristic. This represents the condition 1~3 minutes after the second contingency at which time loads will have recovered to their precontingent levels inherently or been restored by load transformer tapping. No operator intervention is assumed.

Reactive constraints need to be identified for each of the network alternatives considered. The critical condition is the summer peak demand due to combined high real power demand with high reactive demand. The critical contingency for the 500 kV transmission network with a prior outage of HWTS-SMTS line is the loss of HWTS-ROTS line. Table A5-3 summarises the reactive constraints for the different transmission options.

Development Option	Thermal constraint (MVA)	Reactive constraint (MVA)
Do nothing	2600	3820
Termination upgrade	3400	3820
Rowville option	5200	>5200
Cranbourne option	5200	>5200
5^{th} 500 kV	7800	>7800

Table A5-3: Line flow constraints on the remaining 500 kV line/s for N-2 condition

These figures indicate that thermal constraints are always binding the transfer capability from the Latrobe Valley to Melbourne.

Performance of the 500 kV lines

In Victoria, the network owner (and transmission network service provider) must use reasonable endeavours to ensure that transmission network equipment meets the GridCo Benchmark Performance Standards specified in Attachment 11 of the Victorian System Code. Benchmark performance levels are;

Target Maximum Forced Outage Rates:

Cause	Incidents per annum per 100 circuit km
Equipment failure and operator error	1.0
Lightning and storms	0.5

Mean duration of forced outages is 10 hours.

Transmission line lengths of the 500 kV Lines are:

500 kV line	Length (km)
HWTS-SMTS No1	154
HWTS-SMTS No2	154
HWTS-ROTS No4	137

Expected total annual forced outage duration:

10 * (1.0 + 0.5) * (137 + 154 + 154) /100 = 66.75 hours

Probability of line forced outage in any hour:

P_{fo} = 66.75/8760
= 0.00762

The expected performance of the 500 kV transmission lines based on these standards is close to the average performance experienced over the last fifteen tears based on historical records.