Melbourne CBD Security of Supply Enhancement Project

Submission to the Essential Service Commission

Revised version 11 September 2006

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EXECUTIVE SUMMARY

In 2001, electricity supply to the Melbourne Central Business District (**CBD**) was interrupted on two separate occasions. The events, which occurred in January and November, disrupted electricity supplies to tens of thousands of customers, and directly affected a further 100,000 to 200,000 people within and surrounding the CBD.

Independent analyses of these events by Sinclair Knight Merz (**SKM**) found that if the CBD network had been designed to a higher security standard (of "N-1 Secure"[1]), the adverse effects of the two events that occurred in 2001 could have been avoided or reduced in severity.

Independent analysis by SKM also found that:

- of eight similar CBDs in developed economies, Melbourne had the second-lowest security of supply; and

- the costs of loss of supply to the CBD are likely to be very substantial and widespread, with the adverse impacts of such events extending beyond the direct impact on electricity consumers.

In view of these considerations, CitiPower proposed as part of its Price Service Offering for the 2006-10 regulatory period, a project aimed at enhancing the security of electricity supply to the CBD.

In response, the Essential Services Commission (**Commission**) expressed full support for CitiPower's proposed project and said that it considers the project to be a positive step, especially given the low comparative rating that SKM had given to the level of security of supply that currently exists in Melbourne's CBD. However, the Commission excluded the CBD security of supply project from CitiPower's expenditure allowance for the 2006 to 2010 regulatory period because it considered that there is a need for further review and consultation in relation to the following questions:

- What is the most appropriate planning standard for the Melbourne CBD?
- What is the most appropriate project to deliver that standard?
- Who should pay for the project?

This submission addresses these issues, and is intended to assist the Commission in the preparation of an Issues Paper to be released to initiate its formal consultation process on the question of CBD electricity supply security.

This submission is based largely on independent analysis undertaken by SKM at CitiPower's request. In August 2006, SKM updated the work it undertook for CitiPower during the 2006 Electricity Distribution Price Review process. SKM's two updated reports form part of this submission.

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1 Under this standard, the network can withstand the loss of any element and maintain supply to all customers. In addition the network can be subsequently re-configured to withstand a further outage without loss of supply to customers. During the time taken to re-configure (which is targeted to be 30 minutes), there is a risk of supply interruption if a second contingency occurs.

The key points of this submission are as follows:

- The loss of supply incidents in 2001 highlighted shortcomings with the security of supply to the CBD, even though the network complies with the present security standard.

- Qualitative analysis strongly suggests that the adoption of an enhanced security of supply standard for the CBD would be consistent with good electricity industry practice.

- Quantitative evaluation of the benefits (assessed in terms of reduced CBD customer interruption costs only) and the costs of supply security enhancement shows that:

    - the adoption of an "N-1 Secure" planning standard for the CBD is economically justified;

    - a comparison of two options delivering identical levels of capacity and security identifies the installation of additional 220/66 kV transformation capacity at the existing Brunswick Terminal Station providing the most economically efficient way of simultaneously providing the capacity augmentation needed to meet expected demand growth and implementing the "N-1 Secure" standard; and

    - The NPV of the cost and benefits of the security enhancements alone is $0.9M. This figure does not include the additional broad economic benefits that increased security will confer on Melbourne's CBD and surrounding areas.

	$m (2006)
PV capacity related costs	67.4
PV security enhancement costs	40.4
PV benefits of security enhancement	(41.3)
NPV of security enhancements	(0.9)
PV of costs ***with*** security enhancement	66.5

- It is not feasible to meet load growth and to maintain network security standards through the use of embedded generators and customer load curtailment strategies. Such an approach is not feasible due to the widespread specific network locations requiring a high level of customer load curtailment (>300 MVA).

- CitiPower is seeking $42.9m ($2006) over the period 2007-10 to undertake the security enhancement project. Completion of the project will require a further $9.5m in 2011 which will be considered as part of the next regulatory period. The capacity related aspects of the project have already been included as part of the 2006-10 Electricity Distribution Price Review.

- As part of the 2006 Electricity Distribution Price Review process, CitiPower consulted widely on its proposal to increase the security of supply to the Melbourne CBD. Stakeholders have already expressed strong support for the proposal.

- SP AusNet and VENCorp have confirmed that the proposed security enhancement works and the preferred network augmentation option are feasible.

- CBD security of supply enhancement would produce broad economic benefits to Melbourne's CBD and the surrounding areas. Accordingly, the costs for the project should be recovered from all customers in accordance with the network pricing methodologies applied by CitiPower and Transmission Network Service Providers. Assuming that the cost of the project is recovered from all of CitiPower's customers, the impact on the average residential bill over the period 2007-32 would be an increase of approximately 1.8 per cent per annum.

- CitiPower is proposing a timetable that will allow the full benefits of the new planning standards to begin as early as 2011.

CitiPower considers that the case for adoption of the "N-1 Secure" standard for CBD supply has been clearly established. The company looks forward to participating constructively in the Commission's forthcoming consultation process on CBD supply security, with a view to doing everything it can to ensure that the benefits of enhanced CBD supply security can be delivered to Victoria as quickly and efficiently as possible.

1. INTRODUCTION

Background

CitiPower's *2006 Electricity Distribution Price Review Submission to the Essential Services Commission 21 October 2004* (**Price Service Offering**) included a project aimed at enhancing the security of electricity supply to the Melbourne Central Business District. The project would ensure that an appropriate level of electricity supply security applies to the Melbourne CBD, having regard to the potentially very high costs of CBD supply interruptions, as well as the security of supply standards adopted in other comparable cities.

The project was presented separately from other demand-driven augmentation and reinforcement expenditure proposed in CitiPower's Price Service Offering, on the basis that:

- the project would provide the Melbourne CBD with a level of network security above that specified in the *Electricity Distribution Code;* and

- the level of security to be delivered by the project would be higher than that delivered under the base case Price Service Offering.

In preparing its Price Service Offering for the 2006 to 2010 period, CitiPower commissioned two independent analyses by SKM to assess the possible need for an increase in the security of supply to the CBD:

- The first analysis entitled *CitiPower Review of CBD Security of Supply and Planning Standards Final Report 29 July 2004* was included in CitiPower's Price Service Offering. This analysis outlined the rationale for the proposed increase in the security of supply, the options for achieving that increase and the likely costs.

- The second analysis, *Economic Benefits of CBD Security Enhancement* was submitted to the Commission on 26 April 2005 as part of CitiPower's *Response to Essential Services Commission Electricity Distribution Price Review 2006-10 Position Paper*. This second SKM report presented a probabilistic assessment of the benefits of the proposed increase in CBD supply security over the period from 2006-2036.

The Final Decision in the 2006 Electricity Distribution Price Review (EDPR) stated:

> "The disruption of supply to the CBD has a significant impact on the economy. Hence, the Commission fully supports CitiPower's proposed project and considers it a positive step, especially given the low comparative rating that SKM has given to the level of security of supply that currently exists in Melbourne's CBD."

However, the Final Decision excluded the CBD security of supply project from CitiPower's expenditure allowance for the 2006 to 2010 period. The reasons given by the Commission for its decision included, among others, the Commission's view that a project of this type should be subject to further review and consultation on the change in the planning standard that would be required to deliver enhanced security, the cost of meeting that planning standard and how it should be paid for.

In view of the reasons stated for the Commission's decision, CitiPower engaged SKM to revise and update its original reports to:

- incorporate the latest available information on the scope and costs of the options available to increase CBD supply security;
- incorporate updated demand forecasts;
- reflect the latest available information on the likely earliest timing of works that could be undertaken to enhance the security of supply to the CBD; and to
- incorporate the latest available information on the Value of Customer Reliability.

SKM's revised reports[2] form part of this submission.

Purpose and structure of this submission

This submission presents CitiPower's response to the issues identified by the Commission as requiring further review and consultation, namely:

- What is the most appropriate planning standard for the Melbourne CBD?
- What is the most appropriate project to deliver that standard?
- Who should pay for the project?

The purpose of the submission is to assist the Commission in the preparation of an Issues Paper to be released to initiate its formal consultation process on the question of CBD electricity supply security.

The remainder of this submission is structured as follows:

- Section 2 establishes the case for the preferred network solution by:
    - examining the causes and impacts of two Melbourne CBD electricity supply interruptions that occurred in 2001;
    - noting recent outages in other major cities around the world;
    - considering the security standards applying in other comparable CBDs;
    - conducting an economic evaluation of two alternative network development options, with and without security enhancements; and
    - assessing the feasibility of non-network solutions.
- Section 3 outlines the stakeholder consultation and joint planning that has been undertaken so far by CitiPower on the issue of security of electricity supply to the CBD.

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2 These reports are tilted:

> *CitiPower Review of CBD Security of Supply and Planning Standards: Updated Final Report,* August 2006.
>
> *Economic Benefits of CBD Security Enhancements,* Updated August 2006.

- Section 4 provides further technical and cost information regarding the network options, and confirms that the network option identified in section 2 is the preferred option.

- Section 5 provides a summary of the expenditure that CitiPower proposes to incur over the 2006-10 regulatory period to implement the preferred option.

- Section 6 provides an overview of the impacts on average tariffs that arise from the adoption of an enhanced CBD security of supply standard. It also sets out CitiPower's views on how the costs of the preferred option should be recovered.

2. APPROPRIATE SECURITY STANDARD FOR MELBOURNE CBD

2.1 Introduction

This section of the submission examines whether the security of supply standard presently applying to the CBD is appropriate. The section is structured as follows:

- Section 2.2 examines the causes and impacts of two Melbourne CBD electricity supply interruptions that occurred in 2001.

- Section 2.3 summarises a number of recent energy supply interruptions to other major urban centres.

- Section 2.4 briefly examines the security standards applying in other comparable CBDs.

- Section 2.5 provides an overview of the present CBD security criteria.

- Section 2.6 presents the results of the quantitative analysis undertaken by CitiPower to:

    - identify the preferred option for providing additional capacity to meet expected load growth over the next 25 years; and to

    - evaluate the economic benefits of enhancing security of supply.

- Section 2.7 considers the feasibility of non-network options; and

- Section 2.8 presents a summary of key points regarding the appropriate security standard for the Melbourne CBD.

2.2 2001 failure of Melbourne's CBD network

In 2001, two major incidents resulted in supply interruptions to the CBD. These events provided the trigger for CitiPower's review of security standards for the CBD.

The first event occurred in January 2001. A full description of the incident and an analysis of its causes and effects are available on the Commission's website[3]. As a result of this incident, approximately 12,200 customers were off supply for an average of 30 minutes. A further 100,000 people in the CBD area were directly affected by this incident.

A second event occurred on 9 November 2001. A full description of this incident is also available on the Commission's website[4]. As a result of this incident, over 65,000 customers were off supply for up to 64 minutes. It is estimated that a further 100,000 to 200,000 people within and surrounding the CBD were directly affected by this incident.

3 PB Associates, *Exemptions from Reliability Incentive Scheme Review of Applications from CitiPower and TXU*, 2001.

4 PB Associates, *Investigation into Electricity Supply Outage on 9 November 2001 Affecting Melbourne CBD*, 2001.

Independent analyses of these events by SKM[5] suggest that if the CBD network had been designed to a standard of "N-1 Secure"[6], both of the supply interruptions that occurred on 2 January and 9 November 2001 could have been avoided or reduced in severity. In both incidents, the initiating outage took place some days before the loss of supply occurred. Had CitiPower possessed the capability to reconfigure the network at that time, the company would have been in a position to manage the subsequent forced outages.

SKM's analysis also suggests that using customer numbers alone to assess the impacts of CBD outages significantly underestimates the true economic costs. For instance:

- The number of people working, shopping or conducting other activities in the CBD greatly exceeds the number of customers connected to the network[7].

- A loss of supply to the CBD would impact on people in many ways including loss of traffic signalling and public transport, loss of supply to hospitals, health and safety issues associated with the loss of supply to high-rise buildings, disruption of commercial and retailing activity, and disruption of stevedoring at the Port of Melbourne.

The incidents in 2001 also demonstrated that:

- the lack of transfer capacity on the 66 kV network increased the severity of the extent and duration of each outage;

- the lack of 66 kV remote switching capacity contributed to the delay in restoring supply following the 2 January 2001 incident;

- fault level constraints prevented more efficient utilisation of the network, limiting the use of load transfers and preventing the use of spare capacity at adjoining terminal stations; and

- the reliance on West Melbourne Terminal Station (WMTS) - which supplies almost 50 per cent of the CBD load - substantially increases the detrimental consequences of an incident at WMTS.

In summary, the loss of supply incidents in 2001 highlighted shortcomings with the security of supply to the CBD, even though the network complies with the current security standard. The costs of loss of supply to the CBD are likely to be very substantial indeed, as the impacts of such events extend beyond the direct impact on electricity customers.

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5 See SKM's report titled *Review of CBD Security of Supply and Planning Standards: Updated Final Report, August 2006.*

6 Under this standard, the network can withstand the loss of any element and maintain supply to all customers. In addition the network can be subsequently re-configured to withstand a further outage without loss of supply to customers. During the time taken to re-configure (which is targeted to be 30 minutes), there is a risk of supply interruption if a second contingency occurs.

7 The number of people potentially affected by a supply outage in the CBD is over 8 times higher than the number of CitiPower CBD customers.

2.3 Catastrophic incidents in other major centres

In assessing the level of supply security that should be applied to Melbourne's CBD, it is instructive to examine briefly the recent loss of supply events in major cities around the world. The following events show that major network incidents can and do occur in CBDs, and the cost impacts are very significant:

Auckland (1998): On 20 February 1998, a number of 110 kV cables failed resulting in a total loss of supply to the Auckland CBD. The power shortages that followed the initial outage continued in the CBD for the next 2 months (on a rotating interruption basis) resulting in an estimated cost to the community of $75 million[8]. One of the findings of the Ministerial Inquiry[9] that followed the incident was a recommendation that the relevant planning standard be N-2 for the CBD.

Melbourne (1998): An explosion at the Longford Esso/BHP gas processing facility in Sale on 25 September 1998 disrupted gas supply to all of Victoria, including the CBD. Supply was gradually restored from 5 October, firstly to industry, then commercial customers and finally domestic users. The estimated cost of the outage was $1,300 million[10].

New York (2003): On 14 August 2003 a widespread blackout occurred, resulting in a loss of supply to more than 50 million people across the United States and Canada. The major part of the interrupted load was restored within 32 hours but the final restoration took 3 days. It is estimated that the losses in New York City alone were in the order of $1,980 million[11].

Italy, UK, Denmark (2003)[12]: A number of major outages occurred during 2003 including in Italy (on 28 September, with 50 million people affected), Copenhagan and southern Sweden (on 23 September, with 5 million people affected) and London (on 28 August, with 0.5 million people affected).

As noted above, these incidents show that although widespread network failures are not common occurrences in modern economies, when they occur the costs to the community is substantial.

8 Donmoyer RJ, *Darkness Down Under: Major Power Outage Enters Second Month in Auckland New Zealand,* Time International, 1998.

9 Ministerial Inquiry into the Auckland Power Supply Failure, June 1998.

10 Roarty M, Natural Gas Energy for the New Millennium, Research Paper 5 1998-1999

11 Anderson PL & Ilhan KG, *Northeast Blackout Likely to Reduce US Earnings by $6.4 billion,* AEG Working Paper 2003-2, 2003.

12 http://en.wikipedia.org/wiki/List_of_power_outages

2.4 Security standards of other CBDs

CitiPower engaged SKM to examine the security standards applying to other comparable CBDs. SKM was considered to be particularly well qualified to undertake this task given its involvement in Australian and overseas studies of supply security and reliability, and its knowledge of different planning philosophies, network configurations, operational practices and comparative performance of other CBD networks.

In conducting its assessment of the appropriate security standard for the Melbourne CBD, SKM was able to draw on its experience in other CBDs including: Sydney, Brisbane, Adelaide, Wellington, Auckland, Singapore, Glasgow, Johannesburg, Cape Town and Hobart.

In 2003 SKM conducted a confidential survey of supply security of 8 CBDs[13]. SKM ranked the electricity systems supplying these 8 CBDs from "most secure" to "least secure" on the basis of each utility's documented security criteria and their compliance with those criteria. For each CBD, SKM undertook an assessment of loads at risk under specified N-1 contingency conditions. The study concluded that Melbourne had the second-lowest security of supply of the CBDs surveyed.

On the basis of SKM's examination, it would appear that the security standard applied to Melbourne's CBD is somewhat out of step (that is to say, lower) compared with standards applicable in comparable urban centres in Australia and other developed economies. Section 2.5 below describes the present security criteria applied to the Melbourne CBD.

2.5 CitiPower's present CBD security criteria

CitiPower's present planning criteria, at the zone substation and sub-transmission system level, aim to deliver a network that is capable of satisfactorily withstanding any single contingency event at the 50th percentile demand forecast without interruption to customers. This criterion, known as an N-1 standard, provides for the planned or unplanned removal from service of any network element (for instance, a line, transformer, or circuit breaker) at the time of 50th percentile maximum demand loading on the station or system (as appropriate), so that:

- there is no requirement to interrupt customer load;
- voltage levels on the secondary buses of zone substations are maintained within acceptable limits; and
- the loading on all remaining in-service elements is within their thermal limits.
- Hence, under the planning standard presently applied to CBD zone substations and the sub-transmission lines supplying them:
- no customer interruptions are expected to occur following a first order (N-1) contingency;

13 These CBDs could be considered comparable in terms of their populations, electrical loading and business activities.

- supply is expected to be restored to a minimum of 50 per cent of load following a second order (N-2) contingency;
- there is early restoration of supply to a minimum of 50 per cent load for loss of one zone substation;
- there is early restoration of supply up to 50 per cent of load for loss of one sub-transmission level at a terminal station; and
- provision of supply to a minimum of 50 per cent load is maintained for loss of all circuits in one easement.

This planning standard is identical to that employed by the former State Electricity Commission of Victoria. Whilst the *Electricity Distribution Code* (the Distribution **Code**) does not specifically address supply security, the planning standards utilised by CitiPower are broadly consistent with the intent of the Distribution Code.

2.6 The economic case for enhanced security of supply to the CBD

As already noted, the SKM reports commissioned by CitiPower provide strong qualitative support for the proposed enhancement of CBD supply security. In addition, the SKM report titled *Economic Benefits of CBD Security Enhancement* presents a quantitative assessment of some of the economic benefits of the security enhancement project[14].

SKM evaluated the benefits - in terms of the reductions in expected supply interruption ("unserved energy") - that would be attributable to the enhancement of supply security under an "N-1 Secure" standard[15].

The reduction in expected unserved energy was valued at the Value of Customer Reliability (**VCR**)[16]. However, as already noted - and recognised by the Commission itself - the interruption of supply to the CBD can lead to large and widespread costs being incurred across the economy. The impacts of such events extend beyond the direct impact on CBD electricity customers; therefore the costs of a CBD supply interruption are not fully reflected in estimates of the VCR.

Nonetheless, the VCR provides an accepted and transparent basis for valuing at least some of the benefits of supply security enhancement, thus enabling an economic evaluation of supply security enhancement to be undertaken. Such an

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14 As noted in Section 1 of this submission, CitiPower submitted the March 2005 version of that SKM report - to provide the economic justification for its proposed security enhancement project - as part of its *Response to the Essential Services Commission Electricity Distribution Price Review 2006-10 Position Paper*.

15 As previously noted, under this standard, the network can withstand the loss of any element and maintain supply to all customers. In addition the network can be subsequently re-configured to withstand a further outage without loss of supply to customers. During the time taken to re-configure (which is targeted to be 30 minutes), there is a risk of supply interruption if a second contingency occurs.

16 The VCR is a measure of the marginal value of supply reliability to electricity consumers, which is estimated with reference to the marginal costs incurred by consumers in the event of a supply interruption. The VCR value applied by SKM was derived from the December 2002 CRA report commissioned by VENCorp, titled *Assessment of the Value of Customer Reliability (VCR)*. The commercial sector VCR - escalated to June 2006 dollars using the CPI - was adopted in SKM's studies to value the reduction in expected unserved CBD energy due to adoption of the enhanced security standard.

evaluation compares the costs and benefits (where these can be reasonably quantified) of security enhancement over a reasonable study period, in order to assess whether the additional costs involved in providing enhanced supply security are justified.

In estimating the costs involved in providing enhanced supply security, it is important to recognise that the precise scope of the works required to deliver an “N-1 Secure” level of security depends on the network augmentations that are undertaken to meet load growth and to maintain reliability standards over the planning horizon. Thus, the net benefits of security enhancement need to be considered alongside the costs of the alternative network capacity expansion options.

SKM’s report identifies two different options that would meet forecast capacity requirements and provide an “N-1 Secure” level of security to the CBD, as follows:

- Option 1, which involves the re-development of an existing zone substation to establish a new 220/66 kV terminal station on the northern fringe of the CBD; and

- Option 2, which involves the installation of additional 220/66 kV transformation capacity at the existing Brunswick Terminal Station. Note, this Option 2 was presented in CitiPower’s 2006 EDPR Submission of 21 October 2004.

The scope of works and estimated costs of these options are described in further detail in section 4 below.

The two options have been specified so that over the study horizon of 25 years:

- they deliver functionally equivalent levels of reliability (capacity) and security; and

- the size and timing of new capacity investment for each option has been optimised to deliver the maximum net benefit from reductions in expected unserved energy.

In this economic assessment, the preferred option is the one that has the lowest total expected cost to customers, which includes the expected cost of unserved energy.

To determine whether the case for enhanced security is economically sound, it is necessary to identify the incremental costs and benefits of the more stringent “N-1 Secure” standard. Therefore, SKM separately identified for each option the following costs:

- *Capacity related costs* - These are the incremental capital and operating costs associated with provision of capacity only (in effect the costs of meeting forecast demand growth over the planning horizon assuming that the present level of supply security is maintained); and

- *Security enhancement costs* - These are the additional capital and operating costs for each option that would be associated with implementing the more stringent “N-1 Secure” planning standard.

Table 1 below sets out a summary of the results of the evaluation. The amounts shown are present valued (PV) amounts over the first 25 years, expressed in $ million.

Table 1: Summary of results of economic evaluation of options over the first 25 years (base case)[17]

	Option 1 (CBD)	Option 2 (Brunswick)
Costs and benefits of the two options:		
PV capacity related costs	106.0	67.4
PV security enhancement costs	28.8	40.4
PV benefits of security enhancement	(41.3)	(41.3)
Analysis of options:		
PV of costs ***with*** security enhancement	93.5	66.5

Table 1 shows that:

- The shaded cell in the bottom right-hand corner indicates that Option 2 ***with*** security enhancement delivers the lowest net cost to customers. (The PV cost over 25 years of Option 2 with security enhancement is $27 million less than that of Option 1.)

- Implementing Option 2 without security enhancement would lead to higher costs being borne by customers. This is because the total PV benefits of security enhancement ($41.3 million over 25 years) exceed the costs of security enhancement ($40.4 million) over that same period. This demonstrates that the adoption of the more stringent "N-1 Secure" standard is economically justified, based on the valuation (at VCR) of avoided customer interruption costs. As already noted however, the VCR does not capture all of the benefits of CBD security enhancement. Thus, the economic evaluation probably understates the net present value of security enhancement.

- With or without security enhancement, the cost of Option 1 exceeds that of Option 2. Option 1 is therefore not an economically viable option, regardless of the economics of security enhancement.

On the basis of these observations, it can be concluded that under the base case assumptions applied in the economic evaluation, Option 2 coupled with the enhanced supply security standard of "N-1 Secure" is the preferred network solution. Sensitivity testing - details of which are provided in Appendix G - confirms that Option 2 with security enhancement is the preferred network solution across a number of scenarios.

Section 4 sets out further technical details and cost estimates for the two network options both *with* security enhancements[18], while Appendix G provides further details of the economic evaluation. Section 2.7 below examines the feasibility of non-network solutions.

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[17] Key assumptions underpinning the base case are outlined in Appendix G.

[18] For both options, the incremental benefit of the security enhancement exceeds the costs. The purpose of section 4 is to consider each option (with security enhancement) in more detail to assess whether there are matters not addressed in the economic evaluation that may lead to a different choice of options.

2.7 Feasibility of non-network solutions

Section 2.6 examined the preferred network solution to the CBD security of supply issue. The purpose of this section is to examine the feasibility of non-network alternatives to the network development.

Table 2 below sets out a list of demand management / embedded generation resources that, if developed, would provide a security standard equivalent to the proposed security enhancement works.

Table 2: Demand-side resources that would provide an alternative to network development

Demand side management requirements - security enhancement					
CBD zone substation	**Transformer name plate rating MVA**			**2006/07 forecast summer MD**	**DSM required by each zone substation**
	(Installed)	(N-1)	(N-2)	MVA	**MVA**
FR	90	60	30	58.3	30
JA	165	110	55	94.9	55
LQ (NOAC on Tx2)	120	120	60	128.1	60
MP	165	110	55	120.5	55
VM	84	54	27	74.9	27
WA	84	54	27	73.7	27
TOTAL					**254 MVA**

This table shows that the demand side management requirement at each of the major CBD zone substation to achieve a security standard equivalent to the standard that would be provided by the security enhancement works proposed for the network. It can be seen from the table that adding the demand side management response to the (N-2) capacity at each station restores each station to its (N-1) capacity. These demand side management resources would need to be fully available by the end of 2011 in order to provide a potentially viable alternative to the proposed network development.

SKM's report *CitiPower Review of CBD Security of Supply and Planning Standards: Updated Final Report, August 2006,* addressed the subject of non-network options for meeting the demand growth within the CBD (refer chapter 4.5). The report found that whilst it may be theoretically possible to maintain network security standards through the use of embedded generators and customer load curtailment strategies, in practice such an approach is not feasible.

For example, relying on embedded generation would require the installation of 20 to 30 MW per annum over the next five years within the CBD. Such rapid development of embedded generation within the CBD would create adverse environmental impacts in terms of air quality, waste heat and noise which are likely to attract significant community opposition. It is also likely the Environment Protection Authority would impose restrictions on the operation of any embedded generator within the CBD. There are also a number of issues associated with matters such as finding suitable sites for additional embedded generation, the adverse impact of fault levels on the network, and the requirement to geographically spread the generation across the CBD to achieve the required level of supply security. These issues suggest that embedded generation resources alone would be insufficient to provide the required level of supply security.

Demand side management options would require customers across the CBD to curtail demand almost immediately and without notice in the event of a major incident. SKM's analysis suggests there is likely to be limited customer interest in curtailing load in the event of an incident and furthermore, any curtailment would need to be strategically spread across the CBD. Customers curtailing their load would also be expected to disconnect from the network and utilise their emergency generators. Such an option is unlikely to be viable in the longer term as typically, emergency generators are diesel fuelled and raise attendant pollution issues. In addition, emergency generators seldom have the capacity to meet the customer's entire load needs.

2.8 Summary of key points: Appropriate security standard for the Melbourne CBD

SKM's qualitative analysis strongly suggests that the adoption of an enhanced security of supply standard for the CBD would be consistent with good electricity industry practice.

Quantitative evaluation of the benefits (assessed in terms of reduced CBD customer interruption costs only) and the costs of supply security enhancement shows that:

- the adoption of an "N-1 Secure" planning standard for the CBD is economically justified; and
- of the two network options examined, Option 2, which involves the installation of additional 220/66 kV transformation capacity at the existing Brunswick Terminal Station provides the most economically efficient way of simultaneously providing the capacity augmentation needed to meet expected demand growth and implementing the "N-1 Secure" standard .

As noted in further detail in section 3 below, CitiPower has already consulted widely on its proposal to increase the security of supply to the Melbourne CBD. Stakeholders have expressed strong support for the proposal.

3. STAKEHOLDER CONSULTATION AND COMMUNICATION

3.1 Stakeholder consultation and customer research

In the course of assessing the CBD security standard and the options available to enhance supply security, CitiPower has undertaken extensive public consultation and communication with relevant stakeholders, as summarised below:

- CitiPower's Transmission Connection Planning Reports and Distribution System Planning Reports have identified the need to establish an additional transmission connection point (to supply the CBD and surrounding areas) for some years, based on the forecast growth in peak demand. These capacity augmentation proposals and their associated costs were included in CitiPower's capital expenditure benchmark in the 2006 Electricity Distribution Price Review (EDPR) Final Determination.

- A discussion of the proposed security enhancement project, including the proposal to change the planning standard from "N-1" to "N-1 Secure" was set out in CitiPower's 2004 *Distribution System Planning Report*. This report was placed on CitiPower's website in December 2004.

- Details of the proposal have been presented to, and discussed with CitiPower's Customer Consultative Committee, which includes amongst other members, representatives from the Australian Industry Group and St Vincent De Paul. The Committee expressed support for the proposal[19].

- As already noted in section 1, details of, and justification for the project were documented in CitiPower's Price Service Proposal for the 2006-10 regulatory period, which was lodged with the Commission on 21 October 2004.

- CitiPower presented the key elements of its Price Service Proposal - a major part of which was the CBD Security Project - at a number of different forums including:

    - at the Commission's offices on 15 November 2004, the audience for which included customer groups such as EAG, EUCV, and EUAA;

    - at the Melbourne Town Hall on 24 November 2004 (as advertised in the major daily newspapers some time in advance), the audience for which included representatives from major CBD organisations such as RMIT University and Melbourne Central;

    - to the City of Melbourne on 16 February 2005; and

    - to the Melbourne Major Events Corporation on 29 March 2005;

Details of the CBD Security Project were presented to the Victorian Department of Infrastructure and Victoria Police on 15 April 2005 (see Appendix A for further details).

In the course of these consultations:

[19] Powercor Australia and CitiPower Customer Consultative Committee, 2006-10 Electricity Distribution Price Review, 26 August 2005.

- CitiPower received support for the proposed change in the planning standard for the CBD.
- CitiPower received no feedback arguing against the capital expenditure proposed by the company to achieve the improved security of CBD supply.
- No proposals for non-network solutions were advanced[20].

Moreover, CitiPower believes that there is widespread support for the project. Indeed, the City of Melbourne wrote to the Commission[21] on 8 March 2005 on the specific issue of the CBD Security of Electricity Supply stating:

> "The City of Melbourne commends CitiPower Pty on its proposal to make the electricity network more secure, and the proposal in question is fully endorsed."

In other correspondence, the City of Melbourne has expressed support for the project[22].

The Victoria Police also wrote to the Commission in similar terms on 30 May 2005[23], stating that:

> "Recent catastrophic CBD network failures in Auckland, New York, London and Birmingham demonstrate that such failures can occur and when they do they impose significant costs on the community and businesses.
>
> …This office has a close working relationship with representatives from CitiPower and any proposal to make the electricity network more secure, is fully endorsed by this office."

In addition to the public consultation described above, CitiPower sought to identify the views of residential and business customers through a series of focus groups and telephone surveys conducted by Sweeney Research. Amongst other things, customers were asked to consider whether they valued increased security for Melbourne's CBD. The results of the research[24] were as follows:

- 67 per cent of residential customers and 70 per cent of small business customers agreed that the CBD security of supply enhancement proposal was worthwhile;
- customers were prepared to pay a mean premium of 3.1 per cent on their network bill to fund the initiative; and
- customers who initially failed to show interest in enhancing CBD security of supply were asked if they were prepared to pay the actual cost increase required

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20 Proposals for non-network solutions were invited as part of CitiPower's Distribution Planning Reports of December 2004 and December 2005.

21 Letter from David Pritchard, Chief Executive of the City of Melbourne, to Paul Fearon, Chief Executive Officer of the Essential Services Commission.

22 City of Melbourne, *CBD Security of Electricity Supply*, 17 August 2005.

23 Letter from Ian Campbell, Senior Sergeant Victoria Police Counter Terrorism Coordination Unit, Essential Services Team, to Paul Fearon, Chief Executive Officer of the Essential Services Commission.

24 Sweeney Research, *Attitudes to Service Enhancements*, Study No. 14487A and Study No. 14487B, April 2005.

to fund the CBD security of supply enhancement. In these circumstances, more than 70 per cent of respondents said they were willing to pay the additional tariff.

The consultation and customer research undertaken so far by CitiPower has provided stakeholders with substantial information regarding the costs and benefits of CBD security enhancement, as well as a reasonable timeframe within which to assess the merits of the project and make their views known. CitiPower has undertaken both general and targeted consultation, received no contrary feedback, and has gained a strong and positive endorsement from local government.

3.2 Joint network planning and liaison with other relevant planning bodies

CitiPower has been engaged in ongoing discussions with VENCorp regarding the proposed security enhancement project, as part of the regular joint network planning meetings between the two organisations. In particular, VENCorp has been consulted on the range of transmission network capacity augmentation scenarios that could accommodate:

- the expected growth in peak demand, and
- CitiPower's CBD security enhancement works.

More recent consultation with VENCorp has enabled CitiPower to determine the most efficient transmission and distribution network development plan to achieve the enhancement to CBD security of supply, whilst meeting forecast capacity augmentation needs. This consultation has confirmed that the network development scheme proposed by CitiPower during the 2006 EDPR is the most efficient.

Consultation has also been undertaken with SP AusNet on the connection costs for a 66 kV point of connection to the shared transmission network at Brunswick Terminal Station, which is one key component of the preferred network development option (Option 2).

Both VENCorp and SP AusNet have confirmed the feasibility of supplying 66 kV from Brunswick Terminal Station. Appendix H contains the letter received from VENCorp dated 25 July 2006. Appendix I contains the letter received from SP AusNet dated 7 April 2006.

Finally, initial consultation over town planning matters has been undertaken with Melbourne City Council, for the purpose of identifying and managing any particular planning issues that may arise in the course of refurbishing some of the existing CBD substation buildings to accommodate additional infrastructure. The City of Melbourne's Planning Department has indicated that there should not be any requirements for special planning permits outside the council's existing guidelines.

4. FURTHER TECHNICAL AND COST DETAILS FOR THE NETWORK OPTIONS

Sections 4.1 and 4.2 provide further technical and cost details of the two network development options that would achieve the “N-1 Secure” standard for the CBD sub-transmission network. The feasibility of non-network options has been considered in section 2.8.

As already noted in section 2.7, the investment streams associated with both network options contain assets required to provide additional capacity, and other assets that form the security of supply enhancement works. The costs associated with these works are separately identified in the following sections.

4.1 Option 1 (Central CBD transmission option)

This option involves construction of the security of supply enhancement works in concert with the development of a 220/66 kV Terminal Station at the existing Bouverie Street/Queensberry (BSBQ), substation site. The single line diagram of this option is presented in Appendix D.

Option 1 requires the construction of a 220 kV cable from Brunswick Terminal Station to Richmond Terminal Station, via BSBQ. This 220 kV cable would become a new shared network asset.

A key feature of Option 1 is the scope that it provides for future 220 kV development within and surrounding the CBD. As load grows it is increasingly more efficient to transfer large concentrated demands via 220 kV compared to 66 kV. This option allows transfer between terminal stations around the CBD to be made at 220 kV, instead of relying on lower capacity 66 kV ties.

The Option 1 delivers an “N-1 Secure” level of supply security to the CBD through:

- the elimination of multiple transformer-ended feeder configurations;
- improved 66 kV transfer capability between zone substations and terminal stations;
- remote controlled 66 kV switching within CBD zone substations; and
- reduced reliance on the West Melbourne Terminal Station 66 kV connection point.

The distribution or 66 kV security of supply enhancement works accompanying Option 1 are similar to those under Option 2 but modified to suit the different long term development scenario. As Option 1 would provide a new connection point within the CBD, the switching arrangements that are required to achieve “N-1 Secure” at the CBD terminal station are simpler than those required under Option 2.

The following table details the capital cost of Option 1 over the period to 2011 as estimated by SKM. These cost estimates were developed on the same basis as the cost estimates for Option 2 (see section 4.2 below) and were applied in the economic evaluation of the two options[25]

Table 3: Indicative capital costs for Option 1 over the period to 2011 ($2006)

Central CBD 220kV Option (BSBQ 220/66kV Terminal Station with 2x225MVA transformers)					Category
Site	Works	Unit Cost ($2006)	Qty	Total Cost ($2006)	
BSBQ TS	Install new BTS-RTS 220kV cable running via BSBQ (Assuming cable installation is advnced by 20 years compared to VENCorp's plans)	$5,259,277	12	$44,860,824	Shared Transmission Asset Cost
	Install 5x220kV GIS CBs	$2,997,788	5	$14,988,939	Shared Transmission Asset/ Transmission Connection Asset Costs
	Station Refurbishment (220kV+ transformer civils+ 220kV & 66kV switchbay floors)	$15,000,000	1	$15,000,000	Shared Transmission Asset/ Transmission Connection Asset Costs
	Control Room + comms/SCADA	$1,200,000	1	$1,200,000	Shared Transmission Asset/ Transmission Connection Asset Costs
	Install 2 x 220/66kV 225MVA transformers (Allow room for ultimate 3 transformers)	$5,942,983	2	$11,885,966	Base Case: Demand Related Reinforcement
	Station Refurbishment (66kV)	$525,928	1	$525,928	Base Case: Demand Related Reinforcement
	Civil works for 66kV switchbay floor (per 66kV transformer)	$1,051,855	3	$3,155,566	Base Case: Demand Related Reinforcement
	Install 1 x 50MVAr 66kV Capacitor bank	$1,262,226	1	$1,262,226	Base Case: Demand Related Reinforcement
	Install 12x66kV GIS CBs -incl 1 initial cap bank CB (Allow room for ultimate 24x66kV GIS CBs)	$736,299	12	$8,835,585	Base Case: Demand Related Reinforcement
	Install 2x 66kV 120MVA cable from Sub W to BSBQ	$3,786,679	1.95	$7,384,025	Base Case Security Enhancement
	Protection works for both ends of Sub W-BSBQ 66kV cables	$210,371	2	$420,742	Base Case Security Enhancement
	Install 3x66kV 60MVA cables from BSBQ TS to Sub BSBQ	$3,786,679	0.05	$189,334	Base Case: Demand Related Reinforcement
	Protection works for both ends of BSBQ TS Sub BSBQ 66kV cables	$210,371	3	$631,113	Base Case: Demand Related Reinforcement
	Install 3 x 66kV 120MVA cables from BSBQ to VM	$5,680,019	1.95	$11,076,037	Base Case Security Enhancement
	Protection works for both ends of BSBQ-VM 66kV cables	$210,371	3	$631,113	Base Case Security Enhancement
	Re-direct VM-W feeder directly to Sub WA	$210,371	1	$210,371	Base Case Security Enhancement
Sub BSBQ	Install 3x66/11kV 30MVA transformers + 11kV CBs & secondary works	$4,628,164	1	$4,628,164	Base Case: Demand Related Reinforcement
	Station Refurbishment (11kV)	$525,928	1	$525,928	Base Case: Demand Related Reinforcement
Sub VM	Replace 9x66kV isolators with 16 GIS CB's and isolators	$736,299	16	$11,780,780	Base Case Security Enhancement
	Station Refurbishment	$1,051,855	1	$1,051,855	Base Case Security Enhancement
Sub W	Replace 7 x 66kV isolators with 7GIS CB's + isolators with room for expansion to further 4 x 66kV CB's	$736,299	7	$5,154,091	Base Case Security Enhancement
	Station Refurbishment	$1,051,855	1	$ 1,051,855	Base Case Security Enhancement
Sub FR	Install additional 1x 66kV Link	$368,149	1	$368,149	Base Case Security Enhancement
Sub MP	Install additional 1x 66kV Switch Link	$368,149	1	$368,149	Base Case Security Enhancement
	Base Case: Demand Related Reinforcement			**$31,639,809**	Note: Direct costs
	Base Case: Security Enhancement			**$39,497,169**	Note: Direct costs
	Base Case: Shared Transmission Asset / Transmission Connection Asset Costs			**$76,049,763**	Note: Direct costs

Option 1 also includes demand driven augmentation elements similar to Option 2, integrated with the security enhancement works:

- In the case of Option 2 the additional capacity augmentations are provided by new 220/66 kV transformers at Brunswick Terminal Station and the associated 66 kV cable circuits into the CBD.
- In the case of Option 1, the additional capacity augmentations are provided by new 220/66 kV transformers at BSBQ.

If the Option 1 is adopted, there will be no requirement to:

25 An overview of the economic evaluation is provided in section 2.6. Further details are provided in Appendix G.

- augment Brunswick Terminal Station; or
- provide additional 66 kV cables from Brunswick into the CBD.

At the completion of the Central CBD transmission option works, the sub-transmission “N-1 Secure” standard will apply to the 66 kV transformers and 66 kV circuits listed in Table 4 and Table 5 below:

Table 4: Transformers operating at sub-transmission N-1 Secure standard

Zone Substation	Transformers
Victoria Market (VM)	VM No1 66/11kV VM No2 66/11kV VM No3 66/11kV
Bourke Street (JA)	JA No 1 66/11kV JA No 2 66/11kV JA No 3 66/11kV
Little Queen Street (LQ)	LQ No 1 66/11kV LQ No 2 66/11kV LQ No 3 66/11kV
Waratah Place (WA)	WA No 1 66/11kV WA No 2 66/11kV WA No 3 66/11kV
McIlwraith Place (MP)	MP No 1 66/11kV MP No 2 66/11kV MP No 3 66/11kV
Flinders – Ramsden (FR)	FR No 1 66/11kV FR No 2 66/11kV FR No 3 66/11kV

Table 5: Circuits operating at sub-transmission N-1 Secure standard

Source Terminal Station	Circuit
West Melbourne (WMTS)	WMTS-VM1 66kV
	WMTS-VM2 66kV
	WMTS-VM3 66kV
	WMTS-JA1 66kV
	WMTS-JA3 66kV
	JA4-W 66kV
	VM1-LQ1 66kV
	VM3-LQ3 66kV
	VM2-JA4 66kV
	JA4-LQ2 66kV
Richmond (RTS)	RTS-FR1 66kV
	RTS-FR2 66kV

Source Terminal Station	Circuit
	RTS-FR3 66kV
Central CBD (BSBQ)	CBDTS-VM1 66kV - New
	CBDTS -VM2 66kV - New
	CBDTS -VM3 66kV - New
	CBDTS - BSBQ1 66kV - New
	CBDTS – BSBQ 2 66kV - New
	CBDTS – BSBQ 3 66kV - New
	CBDTS -W1 66kV - New
	CBDTS -W2 66kV - New
	VM1–WA1 66kV

4.2 Option 2 (Brunswick 220/66 kV Terminal Station)

This option (referred to as Option 2 throughout this submission and SKM's accompanying reports) has been identified as the preferred option.

The main feature of Option 2 is the development of a 220/66 kV facility at Brunswick Terminal Station (**BTS**). The site is capable of development to an ultimate installed capacity of 4 x 225 MVA (900 MVA) or 675 MVA firm. The major advantages of this option are the size of the ultimate installed capacity and the presence of existing 220 kV circuits of sufficient capacity.

An additional advantage of Option 2 is the capability to shift existing 66 kV loops from both West Melbourne Terminal Station and Richmond Terminal Station. This would allow both increased tie capacity and the flexibility to shift additional load between terminal stations. The simplified single line diagram of the Brunswick 220/66 kV Terminal Station option is shown in Appendix B.

The proposed works will deliver an "N-1 Secure" level of supply security to the CBD by:

- eliminating multiple transformer-ended feeder configurations;
- improving 66 kV transfer capability between zone substations and terminal stations;
- providing remote controlled 66 kV switching within CBD zone substations; and
- reducing reliance on the West Melbourne Terminal Station 66 kV connection point.

Since CitiPower lodged its *Expenditure Submission* of 4 August 2005, the following factors have resulted in the cost estimates of Option 2 increasing:

SKM has confirmed that the 66 kV switching arrangement at zone substation VM (see Appendix C) would not strictly meet the "N-1 Secure" criterion under all feasible contingencies. To ensure the "N-1 Secure" criterion could be achieved, a 66 kV double bus arrangement is recommended at VM. The modified switching arrangement is shown in Appendix C.

The costs for establishment of the 220/66 kV switchyard and transformers at Brunswick Terminal Station have been revised in the light of SP AusNet's recent work in refurbishing part of the existing Terminal Station.

SP AusNet has supplied an updated planning estimate of the cost of works at Brunswick Terminal Station, including allowances for the 220 kV and 66 kV switching requirements.

Appendix F provides a more detailed account of the reasons for the increases in the costs of security enhancement for Option 2, which have occurred since SKM prepared its original report in July 2004.

The revised summary of capital costs for Option 2 over the period to 2011 (in 2006 dollars) is set out in Table 6 below. These cost estimates were prepared by SKM on the same basis as the cost estimates for Option 1(see section 4.1 above) and have been applied in the economic evaluation of the two options[26].

[26] An overview of the economic evaluation is provided in section 2.6. Further details are provided in Appendix G

Table 6: Indicative capital costs for Option 2 for the period to 2011

SKM CBD Report Appendix G Tables 2 & 3 UPDATE Option 2 (Brunswick 220/66kV Terminal Station with 2x225MVA transformers)					Category
Site	**Works**	**Unit Cost ($)**	**Qty**	**Total Cost ($)**	
BTS	Install 2 x 220/66kV 225MVA transformers (including 3x220kV switchgear and 17x66kV GIS double bus CBs)	$33,000,000	1	$ 33,000,000	Shared Transmission Asset/ Transmission Connection Asset Costs
	Install 1 x 50MVAr 66kV Capacitor bank	$1,262,226	1	$ 1,262,226	Shared Transmission Asset Cost (Depends on VENCorp's Requirement)
	Install 1 x 66kV 120MVA cables from BTS to VM	$1,893,340	7.5	$ 14,200,047	Base Case Security Enhancement
	Protection works for both ends of 66kV cable (BTS-VM)	$210,371	1	$ 210,371	Base Case Security Enhancement
	Install 2 x 66kV 120MVA cables from BTS to BQ	$3,786,679	5.33	$ 20,183,001	Base Case: Demand Related Reinforcement
	Protection works for both ends of 66kV cables (BTS - BQ)	$210,371	2	$ 420,742	Base Case: Demand Related Reinforcement
Loop Costs	Connect Loop WB-C-NC at BTS (2 feeder cable terminations)	$105,186	1	$ 105,186	Base Case: Demand Related Reinforcement
	Connect Loop CW-B-NR at BTS (2 feeder cable terminations)	$105,186	1	$ 105,186	Base Case: Demand Related Reinforcement
	O/H 66kV line works for CW loop to BTS (2x4km)	$210,371	8	$ 1,682,969	Base Case: Demand Related Reinforcement
Sub BQ	Install 9 x 66kV CB's + isolators in Double bus configuration	$736,299	9	$ 6,626,689	Base Case: Demand Related Reinforcement
	Install 2 x 66/11kV 60MVA transformers + 11kV switchgear & secondary works	$5,259,277	1	$ 5,259,277	Base Case: Demand Related Reinforcement
	Civil works for switchbay floors (per 66kV transformer)	$1,051,855	3	$ 3,155,566	Base Case: Demand Related Reinforcement
	Station Refurbishment Costs for BQ	$1,167,559	1	$ 1,167,559	Base Case: Demand Related Reinforcement
	Install 2x 66kV 120MVA cable from BQ to sub VM	$3,786,679	1.95	$ 7,384,025	Base Case Security Enhancement
	Protection works for both ends of 66kV cable (BQ-VM)	$210,371	2	$ 420,742	Base Case Security Enhancement
Sub VM	Replace 9x66kV isolators with 19 GIS CB's and isolators (double bus configuration)	$736,299	19	$ 13,989,676	Base Case Security Enhancement
	Station Refurbishment	$1,051,855	1	$ 1,051,855	Base Case Security Enhancement
Sub W	Replace 7x66kV isolators with 7 GIS CBs + isolators (Allow room for ultimate 18x66kV GIS CB's + isolators)	$736,299	7	$ 5,154,091	Base Case Security Enhancement
	Station Refurbishment	$1,051,855	1	$ 1,051,855	Base Case Security Enhancement
	Install 2x66kV 120MVA cables from BQ to W.	$3,786,679	2.0	$ 7,573,359	Base Case Security Enhancement
	Protection works for both ends of 66kV cable (BQ-W)	$210,371	2	$ 420,742	Base Case Security Enhancement
Sub WA	Redirect VM-W feeder to Sub WA directly	$210,371	1	$ 210,371	Base Case Security Enhancement
Sub FR	Install additional 1x 66kV Switch Link	$368,149	1	$ 368,149	Base Case Security Enhancement
Sub MP	Install additional 1x 66kV Switch Link	$368,149	1	$ 368,149	Base Case Security Enhancement
	Base Case: Demand Related Reinforcement			**$36,812,834**	Note: Direct costs
	Base Case: Security Enhancement			**$52,403,434**	Note: Direct costs
	Base Case: Shared Transmission Asset/Transmission Connection Asset Costs			**$36,155,567**	Note: Direct costs

At the completion of the CBD security of supply enhancement works, the sub-transmission "N-1 Secure" standard will apply to the 66 kV transformers and 66 kV circuits listed in Table 7 and Table 8 below:

Table 7: Transformers operating at sub-transmission "N-1 Secure" standard

Zone Substation	Transformers
Victoria Market (VM)	VM No1 66/11kV VM No2 66/11kV VM No3 66/11kV
Bourke Street (JA)	JA No 1 66/11kV JA No 2 66/11kV JA No 3 66/11kV
Little Queen Street (LQ)	LQ No 1 66/11kV LQ No 2 66/11kV LQ No 3 66/11kV
Waratah Place (WA)	WA No 1 66/11kV WA No 2 66/11kV WA No 3 66/11kV
McIlwraith Place (MP)	MP No 1 66/11kV MP No 2 66/11kV MP No 3 66/11kV
Flinders – Ramsden (FR)	FR No 1 66/11kV FR No 2 66/11kV FR No 3 66/11kV

Table 8: Circuits operating at sub-transmission N-1 Secure standard

Source Terminal Station	Circuit
West Melbourne (WMTS)	WMTS-VM1 66kV
	WMTS-VM2 66kV
	WMTS-VM3 66kV
	WMTS-JA1 66kV
	WMTS-JA3 66kV
	JA4-W 66kV
	VM1-LQ1 66kV
	VM3-LQ3 66kV
	VM2-JA4 66kV
	JA4-LQ2 66kV
Richmond (RTS)	RTS-FR1 66kV
	RTS-FR2 66kV
	RTS-FR3 66kV
	FR1-MP1 66kV
	FR2-MP2 66kV
	FR3-W 66kV
	W-MP3 66kV
Brunswick (BTS)	BTS-VM1 66kV - New
	BTS-BQ1 66kV - New

Source Terminal Station	Circuit
	BTS-BQ2 66kV - New
	BQ-W1 66kV - New
	BQ-W2 66kV - New
	BQ- VM1 66kV - New
	BQ- VM2 66kV - New
	VM1-WA1 66kV
	VM2-WA2 66kV

4.3 Preferred Option

On the basis of the results of the economic evaluation (set out in section 2.7) and having regard to the more detailed technical information on each network option (presented above), CitiPower's preferred option is Option 2, which comprises the development of a 220/66 kV transmission connection facility at Brunswick Terminal Station, and associated works. Provisions for the costs of demand related works associated with Option 2 have been included in the price controls detailed in the 2006 EDPR Final Decision.

5. PROPOSED EXPENDITURE OVER 2006-10 REGULATORY PERIOD

Table **9** below provides a detailed summary of the transmission and distribution works (and their budget costs), which CitiPower proposes to commission or undertake over the 2006-10 regulatory period. It is noted that the budget estimate set out below was prepared after SKM had prepared its cost estimates (set out in Table 3 and Table 6) for the purpose of the economic evaluation of Options 1 and 2[4]. The current budgeted costs set out in Table **9** below represent CitiPower's best estimate of the cost and timing of works, based on the best available information at the time of writing this submission.

Table 9: Costs of works over the 2006-10 regulatory period to implement Option 2 (in real $m at June 2006)

Description of capital works	2006	2007	2008	2009	2010	2011	2006-10
Transmission, capacity related[1]							
Install 2 x 220/66kV 225MVA transformers (including 3x220kV switchgear and 17x66kV GIS double bus CBs)	-	3.30	9.90	9.90	9.90	-	33.00
Install 1 x 50MVAr 66kV Capacitor bank	-	-	-	-	-	1.26	-
Total Transmission, capacity related	**-**	**3.30**	**9.90**	**9.90**	**9.90**	**1.26**	**33.00**
Total Transmission, security enhancement	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Distribution, capacity related[2]							
Install 2 x 66kV 120MVA cables from BTS to BQ including Protection works at both ends	-	2.02	5.05	5.05	5.05	3.45	17.16
Install 9 x 66kV CB's + isolators in Double bus configuration – at BQ	-	-	1.33	1.99	1.99	1.33	5.30
Install 2 x 66/11kV 60MVA transformers + 11kV switchgear & secondary works – at BQ	-	-	1.05	2.10	2.10	-	5.26
Station Refurbishment Costs for BQ including civil works for switch bay floors	-	1.17	3.16	-	-	-	4.32

Description of capital works	2006	2007	2008	2009	2010	2011	2006-10
O/H 66kV line works and associated costs for transfer of CW loop & NC loop to BTS (2x4km)	-	-	-	-	-	1.89	-
Total Distribution, capacity related	**-**	**3.19**	**10.58**	**9.14**	**9.14**	**6.67**	**32.04**
Distribution, security enhancement[3]							
Install 1 x 66kV 120MVA cables from BTS to VM including protection works at both ends	-	1.42	3.55	3.55	3.55	2.34	12.07
Install 2x 66kV 120MVA cable from BQ to sub VM including protection works at both ends	-	-	1.48	2.95	2.95	0.42	7.38
Replace 9x66kV isolators with 19 GIS CB's and isolators (double bus configuration)- including station refurbishment works at Sub VM	-	1.05	2.80	4.20	4.20	2.80	12.24
Replace 7x66kV isolators with 7 GIS CBs + isolators (Allow room for ultimate 18x66kV GIS CB's+ isolators)–including station refurbishment works at Sub W	-	1.05	1.03	1.55	1.55	1.03	5.18
Install 2x66kV 120MVA cables from BQ to W including protection works at both ends. Including minor works at substations WA, FR and MP	-	-	1.51	2.27	2.27	2.88	6.06
Total Distribution, security enhancement	**-**	**3.52**	**10.37**	**14.52**	**14.52**	**9.47**	**42.93**

NOTES:

1. Transmission costs shown are estimates of the capital costs incurred by the provider of transmission services. These costs are recovered through transmission tariffs which are effectively "passed-through" to customers by CitiPower in accordance with the Distribution Price Control.
2. An allowance for all distribution capacity related costs is provided in the Distribution Price Control. The costs of this expenditure will be recovered through CitiPower's distribution tariffs
3. No allowance was made in CitiPower's Distribution Price Control for the distribution network costs of security enhancement. These costs will be recovered as a separate "pass-through".
4. The difference between SKM's initial cost estimate for Option 2 and CitiPower's final budget estimate relate principally to the timing of expenditure in 2010 and 2011. CitiPower's budget reflects an expectation that some of the capacity-related expenditure will be undertaken in 2011 (rather than 2010 as indicated in the SKM estimate). The CitiPower budget is consistent with the latest available demand forecasts. The differences between SKM's initial cost estimate for Option 2 and CitiPower's final budget estimate do not affect the relative economics of Options 1 and 2, nor do they affect the economics of security enhancement.

6. TARIFF IMPLICATIONS

This submission and the accompanying SKM reports demonstrate that the proposed CBD security of supply enhancement project produces broad economic benefits to Melbourne's CBD and the surrounding areas. Accordingly, the costs for the project should be recovered from all customers in accordance with the network pricing methodologies applied by CitiPower and Transmission Network Service Providers.

SKM's *Review of CBD Security of Supply and Planning Standard* report, explained that the number of people affected by a large CBD outage is up to 8 times the number of CBD electricity customers. The State Government has recently noted that 'the importance of CBD supply reliability for the smooth running of the economy, and the broader Victorian community is widely acknowledged'[27].

Attempting to allocate the costs of the security enhancement project to those particular customers who benefit from the project would be administratively difficult, if not completely impracticable. Some of the benefits produced by this project will no doubt accrue to customers who reside outside CitiPower's network. However, given the practical difficulties of seeking to recover project costs from non-CitiPower network users, it seems reasonable to spread the cost recovery as wide as is practicable (that is, across the whole of CitiPower's customer base).

Assuming that the cost of the project is recovered from all of CitiPower's customers, the impact on the average residential bill would be an increase of approximately 1.8 per cent per annum or $4.11 over the period 2007-32. Over the current regulatory period (2007-10) the average residential customer bill would increase by $0.93 per annum.

CitiPower understands the Commission considers that one option is to recover the costs of this project from CBD customers only. Whilst this may be a potentially viable option, it does raise broader social, economic and administrative issues that would need to be considered carefully. It is also worth noting that CitiPower does not currently apply any location-specific tariffs. In addition, CitiPower questions whether there is any economic basis for only recovering the costs from CBD customers, given the widespread benefits that the project will deliver.

[27] Minister for Energy Industries, *Electricity Distribution Price Review – Draft Decision*, 19 August 2005.

APPENDIX A. EVIDENCE OF CONSULTATION ON CBD SECURITY ENHANCEMENT

CBD Security of Supply Presentations

24 November 2004 – Melbourne Town Hall

This forum was advertised in the major daily newspapers.

Attendees:

RMIT University

Melbourne Central Office/Retail complex

16 February 2005 - City of Melbourne, 200 Lt Collins St

Attendees:

David Pitchford, CEO

Gordon Duncan, Principal Engineer Assets & Services

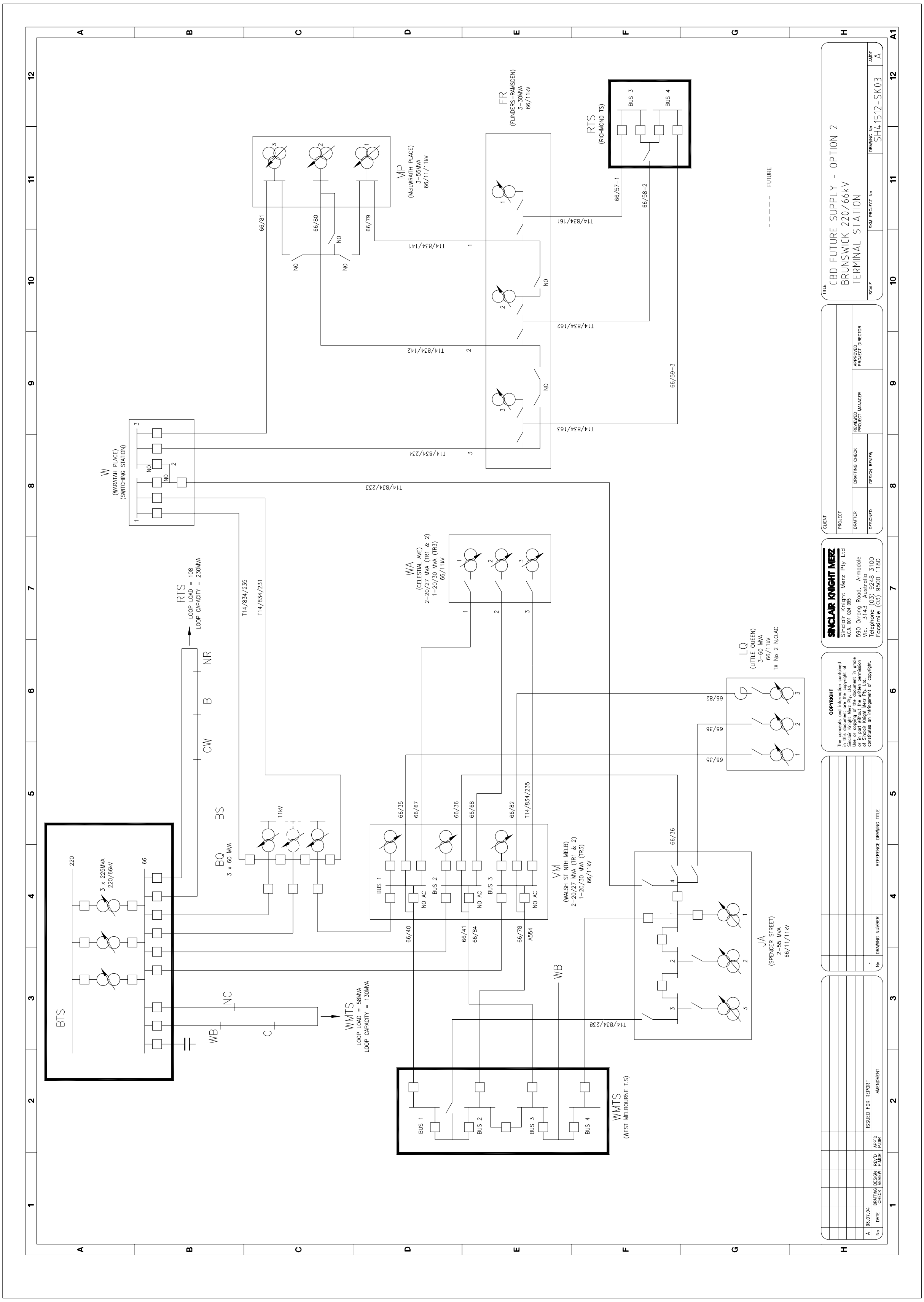
Geoff Robinson, Group Manager Assets & Services

15 April 2005 – Level 9, 80 Collins St: Dept of Infrastructure and Victoria Police

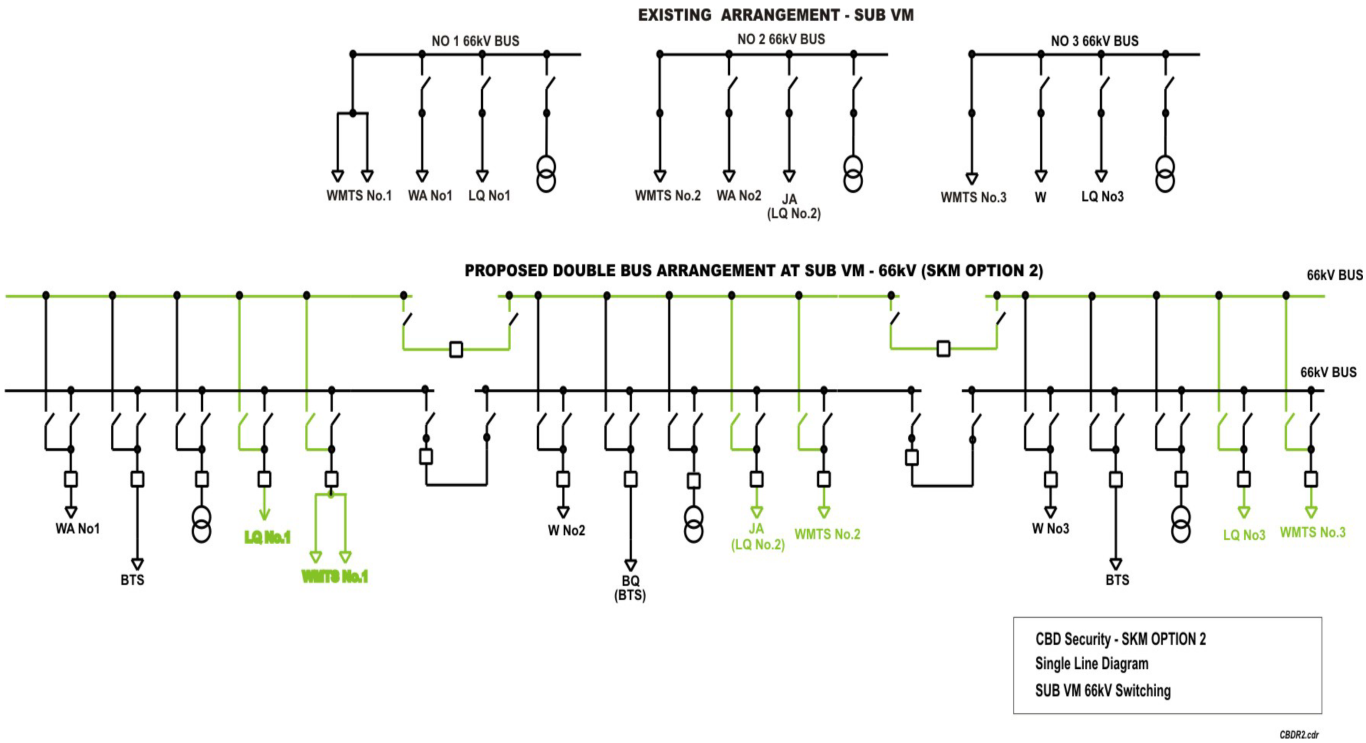
Attendees:

First name	Surname	Title	Department
Matthew	Anderson	Inspector	VicPol
Alex	Badham	Senior Policy Officer	DOI
Peter	Beaumont	Senior Policy Adviser	DPC
Carmel	Collins	Manager, Legal	DOI
David	Harris	Director, Security and Emergency Management	DOI
John	Laursen	Principal policy Officer (Security)	DOI
Uma	Malipatil	Senior Policy Officer	DOI
Greg	McLeish	Manger Supply Security	DOI
Nicola	Mizen	Principal Policy Adviser, Security and Emergency Unit	DPC
Glenn	Mulcahy	Senior Project Officer	DVC
Dugald	Murray	Policy Officer	DOI
Karen	Rendell	Acting Senior Sargent	VicPol CTCV
Robert	Renshaw	Principal Electrical Engineer	KBR
Anthony	Sherry	Project Manager	OCGC-DVC
Sonya	Spencer	Office Manager	DOI
Terry	Spicer	Manager Operations and Emergency Management	DOI
David	Wallish	Manager Policy Projects	DOI
Pat	Watkinson	Acting Senior Sargent	VicPol CTCV

APPENDIX B. OPTION 2 SINGLE LINE DIAGRAM

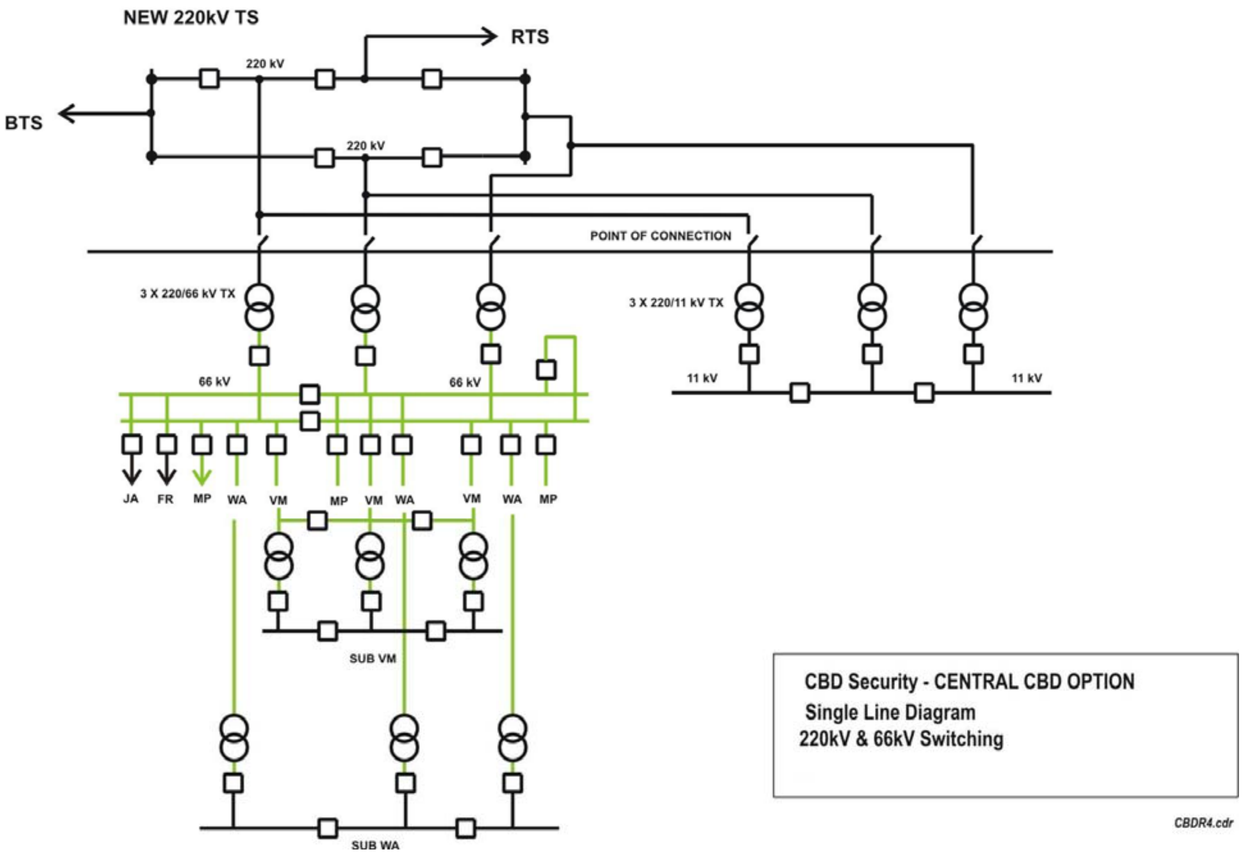


APPENDIX C. OPTION 2: MODIFIED FOR SWITCHING ARRANGEMENTS AT ZONE SUBSTATION VM

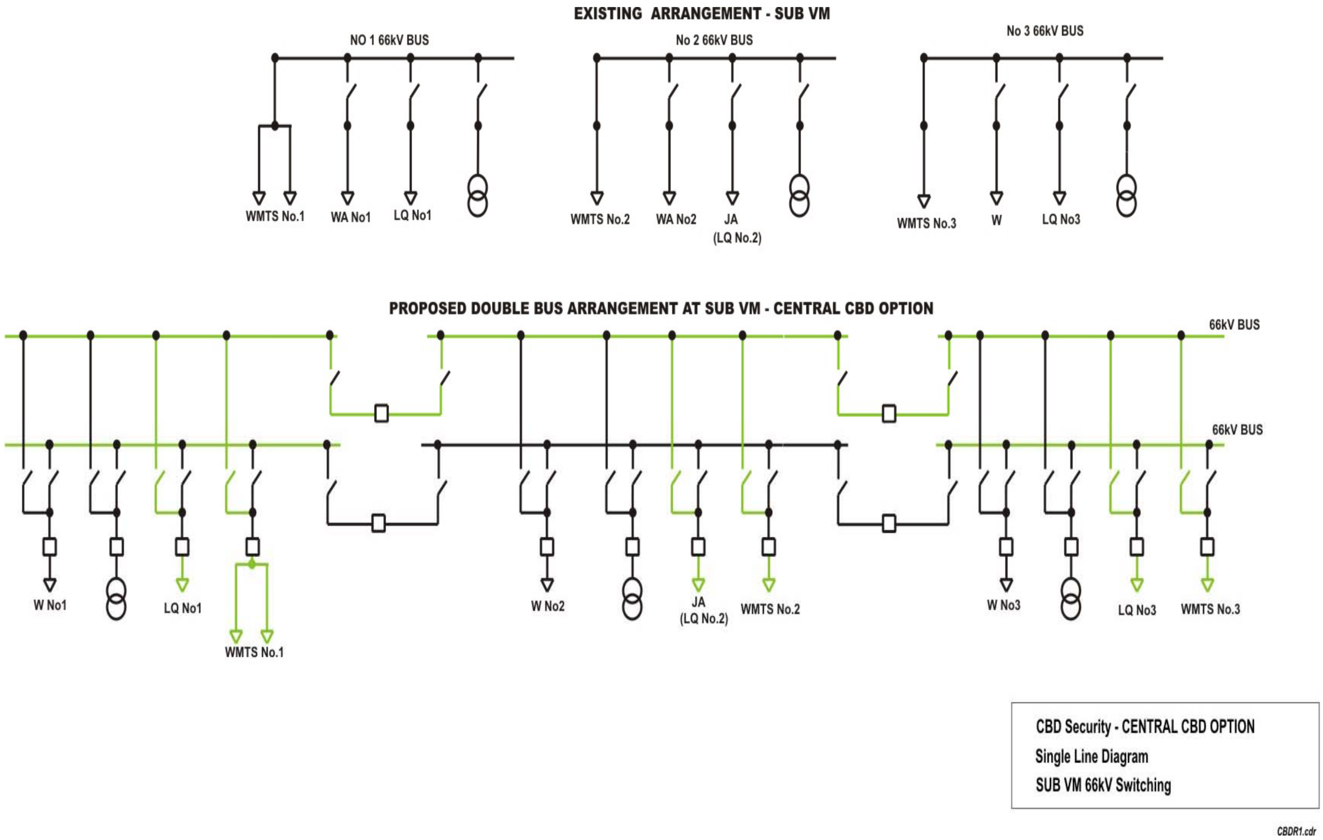


APPENDIX D. OPTION 1 SWITCHING ARRANGEMENTS AT CBD TERMINAL STATION

PROPOSED ARRANGEMENTS AT NEW 220 kV TS



APPENDIX E. OPTION 1 SWITCHING ARRANGEMENTS AT SUB VM



APPENDIX F. REASONS FOR INCREASES IN SECURITY ENHANCEMENT COSTS FOR OPTION 2

Table 10 below provides a summary of the reasons for the increases in the costs of security enhancement for Option 2, which have occurred since SKM prepared its original report in July 2004.

Table 10: Variance Analysis

Works	**2004 Cost estimate** (in 2004 dollars)	**2006 Cost estimate** (in 2006 dollars)	Explanation of difference
BTS66kV Establishment Costs (Capacity related)	$17.2m	$34.2m	Based on latest cost estimates provided by SP AusNet & increased switchgear cost due to increase in the number. of CB's required.
Sub VM Switching (Security enhancement)	$10.5m	$15.0m	Based on increased switchgear cost due to an increase in the number. of CB's required.
Sub W Switching (Security enhancement)	$12.5m	$14.2m	Based on increased switchgear cost due to an increase in the number. of CB's required.
Sub BQ (Security enhancement)	$16.4m	$22.2m	Based on increased switchgear and cable cost.

APPENDIX G. FURTHER DETAILS - ECONOMIC EVALUATION

G1 Introduction

This Appendix provides a description of the economic evaluation undertaken of the two network development options, with and without security enhancement. The Appendix is structured as follows:

- Section G2 provides an overview of the economic evaluation methodology, while section G3 provides a summary of results of the evaluation under the base case assumptions applied. These sections largely repeat information already presented in section 2.6 of the submission, however they are included here in the Appendix for completeness.
- Section G4 summarises the key assumptions underpinning the base case. It also provides an overview of the results of sensitivity testing around those base case assumptions.
- Section G5 provides a summary of capital expenditure cash flows for each option.

G2 Overview of methodology

The objective of the evaluation was to:

- identify the network capacity expansion option that would meet expected CBD and inner-urban load growth over a study horizon of 25 years, whilst maximising net benefits under the current planning standard; and to
- determine whether, in the context of the capacity augmentation investment required over the next 25 years, the adoption of a more stringent “N-1 Secure” standard would be economically justified.

The precise scope of the works required to deliver an “N-1 Secure” level of security depends on the network augmentations that are undertaken to meet load growth and to maintain reliability standards over the planning horizon. Thus, the net benefits of security enhancement need to be considered alongside the costs of the alternative network capacity expansion options.

In view of this, two network development options (Option 1 - CBD terminal station development, and Option 2 - Brunswick terminal station development) were specified so that over the study horizon:

- they deliver functionally equivalent levels of reliability (capacity) and security; and
- the size and timing of new capacity investment for each option is optimised to deliver the maximum net benefit from reductions in expected unserved energy.

Under this approach, the preferred option is the one that has the lowest total expected cost to customers, which includes the expected cost of unserved energy. To determine whether the case for enhanced security is economically sound, the incremental costs and benefits of the more stringent “N-1 Secure” standard were separately identified and evaluated. Accordingly, the following costs were identified separately for each option:

- *Capacity related costs* - These are the incremental capital and operating costs associated with provision of capacity only (in effect the costs of meeting forecast demand growth over the planning horizon assuming that the present level of supply security is maintained); and

- *Security enhancement costs* - These are the additional capital and operating costs for each option that would be associated with implementing the more stringent "N-1 Secure" planning standard.

The benefits of adopting the enhanced security standard were evaluated in terms of the reduced supply interruption costs that would be incurred by customers. SKM undertook studies to estimate the reduction in expected unserved energy attributable to the adoption of the "N-1 Secure" standard[28]. The reductions in expected unserved energy were valued at the Value of Customer Reliability (VCR)[29]. It is noted that the interruption of supply to the CBD can lead to large and widespread costs being incurred across the economy. The impacts of such events extend beyond the direct impact on CBD electricity customers; therefore the costs of a CBD supply interruption are not fully reflected in estimates of the VCR.

The capital costs of implementing the enhanced security standard were estimated by SKM[30] and the incremental operations and maintenance costs were estimated by CitiPower.

A discounted cash flow model was used to calculate the present value of the costs and benefits for each option. A study horizon of 25 years was adopted on the basis that reasonably robust long-term network development options could be specified over such a period. However, both options involve staged sequences of substantial capital expenditure over the next 25 years, which would be expected to continue to produce outputs (benefits) for many years after the end of the 25 year study horizon[31]. Given this consideration, the capital costs for each option were included in the cash flow analysis as real annuities (or 'equivalent annualised costs'). The annuity value was calculated by amortising the capital cost (including an allowance for financing during construction) over the 40-year life of the assets. A real discount rate of 6.4% (effectively, pre-tax) was applied in all of the base case discounted cash flow calculations.

Under this approach, the total capital costs of each option are apportioned uniformly across all years of each asset's expected life. This approach enabled the calculation of a total present value cost for each option (over the 25-year study period) in a manner that took into account the fact that under both options, the network assets installed over the next 25 years will have substantial remaining service potential at the end of the study period. This approach provides an effective means of ensuring that:

- the costs of the options are compared on a like-for-like basis where the study horizon is materially shorter than the lives of the assets included in the discounted cash flow model; and

- the net benefit of security enhancement over the first 25 years is evaluated in a manner that recognises that the security enhancement capital expenditure has an expected life that extends well beyond the study horizon.

---

28 SKM, *Economic Benefits of CBD Security Enhancements*, Updated August 2006.

29 The VCR is a measure of the marginal value of supply reliability to electricity consumers, which is estimated with reference to the marginal costs incurred by consumers in the event of a supply interruption. The VCR value applied by SKM was derived from the December 2002 CRA report commissioned by VENCorp, titled *Assessment of the Value of Customer Reliability (VCR)*. The commercial sector VCR - escalated to June 2006 dollars using the CPI - was adopted in SKM's studies to value the reduction in expected unserved CBD energy due to adoption of the enhanced security standard.

30 SKM, *CitiPower Review of CBD Security of Supply and Planning Standards: Updated Final Report*, August 2006.

31 The average expected life of the assets installed under each option is approximately 40 years.

G3 Summary of results

Table 11 below sets out a summary of the results of the evaluation. The amounts shown are present valued (PV) amounts over the first 25 years, expressed in $ million at 2006 prices.

Table 11: Economic Analysis

	Option 1 (CBD)	Option 2 (Brunswick)
Costs and benefits of the two options:		
PV capacity related costs	106.0	67.4
PV security enhancement costs	28.8	40.4
PV benefits of security enhancement	(41.3)	(41.3)
Analysis of options:		
PV of costs ***with*** security enhancement	93.5	66.5

The table above shows that:

- The shaded cell in the bottom right-hand corner indicates that Option 2 ***with*** security enhancement delivers the lowest net cost to customers. (The PV cost over 25 years of Option 2 with security enhancement is $27 million less than that of Option 1.)

- Implementing Option 2 without security enhancement would lead to higher costs being borne by customers. This is because the total PV benefits of security enhancement ($41.3 million over 25 years) exceed the costs of security enhancement ($40.4 million) over that same period. This demonstrates that the adoption of the more stringent "N-1 Secure" standard is economically justified, based on the valuation (at VCR) of avoided customer interruption costs. As already noted however, the VCR does not capture all of the benefits of CBD security enhancement. Thus, the economic evaluation probably understates the net present value of security enhancement.

- With or without security enhancement, the cost of Option 1 exceeds that of Option 2. Option 1 is therefore not an economically viable option, regardless of the economics of security enhancement.

On the basis of these observations, it can be concluded that under the base case assumptions applied in the economic evaluation, Option 2 coupled with the enhanced supply security standard of "N-1 Secure" is the preferred network solution. Sensitivity testing - details of which are provided in section G4 below - confirms that Option 2 with security enhancement is the preferred network solution across a number of scenarios.

G4 Base case assumptions and sensitivity testing

Table 12 below provides a summary of the key assumptions applied in the base case economic evaluation. The table also shows the impact of varying these key assumptions on the overall results of the economic evaluation.

Table 12: Sensitivity Analysis

Assumption or parameter	Assumption or value applied in base case	Alternative value(s) adopted for sensitivity testing purposes	Impact of this variation on the results of the evaluation
Operating costs	Incremental operating costs equate to 1.0% per annum (in real terms) of the initial capital cost of the assets for security enhancement and capacity augmentation works.	50% increase	The total cost of Option 2 with security enhancement is $28.7 million below Option 1. Option 2 with security enhancement therefore remains the preferred option. The NPV of security enhancement under Option 2 is reduced from $0.9 million (base case) to minus $1.6 million.
		50% decrease	The total cost of Option 2 with security enhancement is $25.3 million below Option 1. Option 2 with security enhancement therefore remains the preferred option. The NPV of security enhancement under Option 2 is increased to $3.5 million.
Installation of second Richmond to Brunswick Cable[32]	Advanced by 20 years (compared to VENCorp's present plans) under Option 1	Advanced by 5 years under Option 1	The total cost of Option 2 with security enhancement is $4.2 million below Option 1. Option 2 with security enhancement therefore remains the preferred option.
Capital cost of security enhancement works	As per SKM's *Review of CBD Security of Supply and Planning Standards Updated Final Report,* August 2006.	Increase SKM estimates by 20%	The total cost of Option 2 with security enhancement is $24.7 million below Option 1. Option 2 with security enhancement therefore remains the preferred option. NPV of security enhancement under Option 2 is reduced to minus $7.1 million over the first 25 years.
		Reduce SKM estimates by 20%	Option 2 with security enhancement remains the preferred option. NPV of security enhancement under Option 2 is increased to $9.0 million over the first 25 years.
Quantity of unserved energy benefits due to security enhancement	As per SKM's updated *Economic Benefits of CBD Security Enhancement* report	20% increase	NPV of security enhancement under Option 2 is increased to $9.2 million over the first 25 years.
		20% decrease	NPV of security enhancement under Option 2 is reduced to minus $7.3 million over the first 25 years.
Discount rate	6.4% real (pre-tax)	6% real 7% real	Increases NPV of security enhancement under Option 2 to $3.2 million over 25 years. Reduces NPV of security enhancement under Option 2 to minus $2.1 million over 25 years.

[32] Option 2 does not require the installation of the second Richmond to Brunswick Cable.

APPENDIX H. LETTER RECEIVED FROM VENCORP DATED 25 JULY 2006

VENCorp

Victorian Energy Networks Corporation

25 July 2006

Mr Garry Audley
General Manager CitiPower Network
Locked Bag 14031 MCMC
VIC 8001

Dear Garry,

RE: MELBOURNE CBD SECURITY OF ELECTRICITY SUPPLY ENHANCEMENT PROJECT

I refer to your letter dated 27 June 2006 regarding Citipower's proposal to improve the security of electricity supply to Melbourne's Central Business District ("CBD Project"). VENCorp welcomes this opportunity to provide planning information with respect to the Victorian shared transmission network ("shared network") to assist in your assessment of the CBD project.

Our understanding is that CitiPower is considering alternative options ("CBD Options") of establishing 220/66 kV transformation at the existing Brunswick terminal station, or at a new CBD terminal station, to increase the security of CBD electricity supply and to supply additional load. Whereas new transformation at Brunswick would connect to the existing 220 kV shared network, new CBD transformation would need to have the shared network extended to the CBD via underground cable.

The analysis and results presented in this letter are preliminary in nature, based on a number of assumptions and long term estimates, which may or may not ultimately be realised. Therefore this information should only be used for the purposes of undertaking high level feasibility assessments, comparing the alternative CBD supply options.

The main shared network impact VENCorp has identified in comparing the CBD options is that the shared network development would be more expensive over the long term for the new underground 220 kV connection to the CBD, compared with the Brunswick option, by an estimated present value of $60M[1]. VENCorp has not attempted to assess whether CitiPower's or VENCorp's proposals can be accommodated satisfactorily within the relevant stations, however we understand that SP AusNet has advised Citipower that the Brunswick 220/66 kV options can be accommodated.

1 Shared Transmission Network impacts of CitiPower's CBD security enhancement

VENCorp's findings and comments relating to the CBD Options follow:

- Augmenting shared network transformation capacity to supply growing eastern metropolitan Melbourne demand is forecast to continue as the main focus of Melbourne's shared network development for the next 20 years. The permanent load transfers CitiPower proposes may not change these augmentation timings, provided the 220 kV Keilor-

[1] This value may be reduced by approximately $15 M if two rather than three 220 kV supplies to the new CBD terminal station are found to be adequate.

Level 2 Yarra Tower, World Trade Centre, Siddeley Street, Melbourne Vic 3005 Correspondence to: PO Box 413, World Trade Centre Vic 8005
Telephone: (03) 8664 6500 Facsimile: (03) 8664 6511

Thomastown lines, supplying almost all transfers from West Melbourne, remain in service. VENCorp expects that these ties can stay closed until 2025. "No Load Transfers" development timings in Attachment 1 are determined by extrapolating VENCorp's Terminal Station Demand Forecasts issued in September 2005.

- VENCorp expects the Rowville-Richmond transmission line uprating date will not be affected by the proposed permanent load transfers from Richmond, as they offload the Brunswick-Richmond line, with little effect on Rowville-Richmond line loading.
- VENCorp expects that the temporary subtransmission transfer capacity CitiPower proposes for use under outage conditions could temporarily reverse most of these "permanent" load transfers operationally, avoiding any advance in shared network timings.
- Proposed permanent load transfers from West Melbourne terminal station may defer uprating the Keilor-West Melbourne line well beyond the 2015 previous timing. They may also defer Keilor 500/220 kV transformation augmentation, if economic development requires the Keilor-Thomastown lines to operate open normally, from 2025.
- VENCorp expects CitiPower's proposals to supply the CBD via a 66 kV connection at Brunswick terminal station will have much lower shared network costs than its CBD terminal station proposal. Apart from replacing one tower and two spans of the Brunswick-Thomastown 1 line at Thomastown, VENCorp expects the existing shared network supply will provide a Brunswick 66 kV connection, with appropriate security and thermal ratings.
- VENCorp also expects the shared network supply to a CBD terminal station would be a high cost underground cable. To provide comparable security to Melbourne's other CBD supplies, VENCorp has assessed the CBD option using three separate 220 kV circuits on two independent easements, which is a variation to CitiPower's CBD option. Procuring easements and obtaining planning permission need much engineering before cost differentials can be identified, and lead times would likely be a minimum of 2 years.

2 Relevant Shared Network Indicative Development Options and Costs

Attachment 1 provides relevant shared network development indicative timings and costs for each of the CBD Options, and without these proposals ("No load transfers"), for thirty years, using data and capabilities in Attachment 2.

Augmentation timings in Attachment 1 have been determined using peak loads forecast to arise under normal system conditions at each distribution point of connection to the transmission network. VENCorp considers shared network capability would usually be available to supply these loads, plus the temporary load transfers shown in Table A5 of Attachment 2. Also VENCorp expects that these temporary load transfer subtransmission facilities could be used operationally, at peak load times, following outage of a shared network element, if this would avoid reducing supply to customers.

Other possible future shared network developments that are not expected to be differently impacted by the alternative CBD options are excluded from Attachment 1. These include:

- additional 500 kV lines and associated works, related to additional generation;
- works related to interconnection transfers and/or load growth outside the metropolitan area; and
- additional reactive compensation.

If you have any queries or require further information in this regard, please contact Joe Spurio, Manager Electricity Planning, on (03) 8664 6613.

Yours faithfully,

Ges Graeme Cook
General Manager Development

Att:

ATTACHMENT 1 RELEVANT SHARED NETWORK INDICATIVE DEVELOPMENTS

The following table provides relevant shared network development, indicative timings and costs for each of the CBD Options, and without these proposals ("No load transfers"), for thirty years, using data and capabilities in Attachment 2. A brief summary of the options is:

BTS Option 1:

- 3 new 66kV supplies from BTS to CBD (i.e. subs BQ, VM & WA);
- New CBD distribution works to enhance supply security;

BTS Option 2:

- 3 new 66kV supplies from BTS to CBD (i.e. subs BQ, VM & WA);
- New CBD distribution works to enhance supply security;
- Transfer subtransmission loops from RTS and WMTS to BTS;

CBD TS:

- New 220 kV underground cables providing a three circuit supply to a new CBD terminal station,
- New CBD distribution works to enhance supply security;

No Load Transfers:

- As proposed in Vision 2030, augment shared network using mainly overhead construction lines, except for a possible Rowville-Richmond 220 kV underground cable beyond 2015, needed similarly for all options considered.

Development (post ROTS A2 / MLTS A2 transformer committed projects)	Cost ($M)	No load transfers	BTS Option 1	BTS Option 2	CBD TS
Replace Brunswick-Thomastown 1 line last tower (at TTS)	1		2026[2]	2016	2022
Extend Brunswick-Richmond 220 kV line using underground cable to form a Brunswick-CBD TS-Richmond line (12 km)	63	-	>2040	2032	2010
West Melbourne-CBD TS-220 kV line using underground cable (5 km)	25	-	> 2040	2040	2016
Next eastern metro 1000 MVA 500/220 kV transformer	35	2012	2012	2012	2012
Keilor-West Melbourne 220 kV line uprating	15	2015	2031	2033	2031
Switch Rowville-Thomastown 220 kV line at Ringwood	3	2015	2015	2015	2015
Next eastern metro 1000 MVA 500/220 kV transformer	30	2017	2017	2017	2017
Switch Hazelwood-Rowville 500 kV line at	8	2017	2017	2017	2017

[2] Financial year of service (ending 30 June)

Development (post ROTS A2 / MLTS A2 transformer committed projects)	Cost ($M)	No load transfers	BTS Option 1	BTS Option 2	CBD TS
Cranbourne					
Rowville-Richmond 220 kV line uprating	25	2018	2018	2018	2018
Next eastern metro 1000 MVA 500/220 kV transformer	30	2021	2021	2021	2021
Thomastown 220 kV bus tie works & open Keilor-Thomastown lines	5	2025	2025	2025	2025
Third South Morang 700 MVA 330/220 kV transformer	20	2025	2025	2025	2025
Next western metro 1000 MVA 500/220 kV transformer	30	2028	2033	2033	2033
Next western metro 1000 MVA 500/220 kV transformer	30	2035	2040	2040	2040

ATTACHMENT 2 SUPPORTING DATA INPUTS AND NETWORK CAPABILITIES

The following load and capability data contained in this attachment provides the basis for VENCorp's assessment of the CBD Options.

Tables A1-3 present the distribution point of connection 10th percentile summer peak demand forecasts VENCorp has extrapolated from the indicative loadings CitiPower has provided for its CBD supply enhancement options and other distributor forecasts. These forecasts provide the basis of VENCorp's indicative 30 year alternative shared network developments for each of the CBD Options.

As CitiPower clarified by email, these tables are based on successive development of the proposed new connection points at Brunswick and the CBD- initially at Brunswick in Tables A1 and A2 and initially in the CBD in Table A3.

TABLE A1 – Point of Connection Loads (MW) - BTS 66 kV (no overhead line loop transfers)

Year	2009/10	2019/20	2029/30	2039/40
Stations				
BTS	306	505	681	924
CBD TS	0	0	0	0
RTS	687	863	1,164	1,580
Other East Metro	3,848	5,095	6,889	9,502
Total East Metro	4,841	6,463	8,734	12,006
WMTS	386	406	548	743
Other West Metro	1,402	1,810	2,396	3,198
Total West Metro	1,788	2,216	2,944	3,941

TABLE A2 – Point of Connection Loads (MW) - BTS 66 kV (with overhead line loop transfers)

Year	2009/10	2019/20	2029/30	2039/40
Stations				
BTS	306	715	965	970
CBD TS	0	0	0	339
RTS	687	719	970	1,317
Other East Metro	3,848	5,095	6,889	9,502
Total East Metro	4,841	6,529	8,824	12,128
WMTS	386	340	458	622
Other West Metro	1,402	1,810	2,396	3,198
Total West Metro	1,788	2,150	2,854	3,820

TABLE A3 – Point of Connection Loads (MW) - CBD terminal station

Year	2009/10	2019/20	2029/30	2039/40
Stations				
CBD TS	287	546	540	540
BTS	92	116	353	672
RTS	573	720	972	1,319
Other East Metro	3,848	5,095	6,889	9,502
Total East Metro	4,800	6,477	8,754	12,033
WMTS	427	391	528	717
Other West Metro	1,402	1,810	2,396	3,198
Total West Metro	1,829	2,201	2,924	3,915

Table A4 presents the indicative connection asset station ratings of CitiPower's alternative options.

TABLE A4 – Proposed Connection Asset Ultimate Ratings

	BTS 66 kV	CBD TS 66 kV
Transformer Continuous rating (MVA)	225	225
Transformer Summer cyclic rating (MVA)	270	270
Station ultimate *n-1* Summer cyclic rating (MW)	3 x 270 = 810	2 x 270 = 540

Table A5 presents the indicative subtransmission capability to transfer load between proposed new stations and existing stations, in addition to supplying the point of connection loads in Tables A1-3. Subtransmission transfers between separate terminal station pairs may occur independently, including concurrently, although their use may be restricted by connection asset capacities. The data in Tables A4 and A5 was provided by CitiPower in emails further to its letter. These emails also clarified that all loadings and transfers may be assumed to be close to unity power factor.

TABLE A5 – Subtransmission load transfer capability (MW)

	To BTS / CBD TS 66 kV
From RTS 66 kV	+240 MW / -150 MW
From WMTS 66 kV	+240 MW / -280 MW

Tables A6 and A7 present shared network indicative *n-1* capabilities needed to supply Melbourne metropolitan area loads under each of CitiPower's options. Table A6 presents the capabilities of the 220 kV lines traversing Melbourne from Cranbourne in the east to Geelong in the west, and Table A7 presents the capabilities of the transformation supplying these lines.

Aiming to achieve consistency and allow comparisons between loads, and line and transformer capabilities in these tables:

- Line and transformer capabilities include about 80% of generation connected directly to the metropolitan 220 kV network (i.e. Yallourn W, Newport, Laverton North and Somerton);
- Line capabilities include Thomastown and Keilor loads that usually may not be supplied by 220 kV lines; and
- Loads greater than capabilities appear for 2039/40, signifying that additional generation, yet to be identified, may then also be connected to the metropolitan 220 kV network, or that additional shared network capability may be needed. This will not impact assessment of CitiPower's proposals.

TABLE A6 – SHARED NETWORK METRO 220 kV LINE *n-1* CAPABILITIES

Year	BTS Option 1 (MW)	BTS Option 2 (MW)	CBD TS (MW)
2005/06	11,400	11,400	11,400
2009/10	11,400	11,400	11,400
2019/20	12,800	13,000	12,800
2029/30	13,400	13,400	13,400
2039/40	14,350	14,350	14,350

TABLE A7 – SHARED NETWORK METRO TIE TRANSFORMATION *n-1* CAPABILITIES

Year	BTS Option 1 (MW)	BTS Option 2 (MW)	CBD TS (MW)
2005/06	8,200	8,200	8,200
2009/10	9,200	9,200	9,200
2019/20	11,000	11,000	11,000
2029/30	12,600	12,600	12,600
2039/40	14,400	14,400	14,400

Values in Tables A6 and A7 exclude subtransmission transfer capabilities, shown in Table A5, consistent with their definition as shared network capabilities, although use of these subtransmission transfer capabilities, when available, is assumed in shared network developments presented in Attachment 1.

APPENDIX I. LETTER RECEIVED FROM SP AUSNET DATED 7 APRIL 2006

SP AusNet™
A member of Singapore Power Group

7 April 2006

Neil Watt
CitiPower Pty Ltd
Locked Bag 14031
Melbourne VIC 8001

Dear Neil,

Planning Estimate – CBD augmentation – BTS 66 kV option

I refer to our 4 April 2006 meeting with you, where you requested an initial estimate for a 66 kV supply at Brunswick Terminal Station based on the attached 66 kV single line diagram, by today. We are pleased to be able to respond to your request within the desired timeframe.

Our planning estimate for the SP AusNet component of a CBD augmentation based on 66 kV at BTS is $33M. This includes 220 kV augmentations, two 220/66 kV transformers and the 66 kV facility suggested by the attached single line diagram. This includes contingency amounts for "brown fields" site factors, and for project contingencies and risks.

The following factors have been taken into account in the planning estimate:

- We have considered the likely configuration required for the 220 kV connections of the 220/66 kV transformers, that would provide relatively straight forward operation and standard protection systems arrangements. Provision has been made in the conceptual 220 kV layout for a second 220 kV cable, as this remains a strong likelihood.
- The reconfigured 220 kV is likely to be a shared network augmentation that would be carried out for VENCorp to VENCorp's requirements. However, given this is an indicative estimate for option assessment only, we have not separated out the shared network component of the costs.
- We have considered the likely location of 220/66 kV transformers.
- We have considered the likely location of the 66 kV switchgear. Site constraints suggest a GIS solution.

The following factors have been intentionally excluded from the planning estimate:

- 66 kV feeder cable termination costs.
- 66 kV feeder routes within the terminal station site.
- Telecommunications costs for 66 kV feeder teleprotection.
- Wider shared network augmentation costs, as it is not known if any are required.

SPI PowerNet Pty Ltd *ABN 78 079 798 173*
A subsidiary of SP Australia Networks (Transmission) Pty Ltd
Level 17, 452 Flinders Street Melbourne Victoria 3000 Australia Locked Bag 14051 Melbourne City Mail Centre Victoria 8001 Australia
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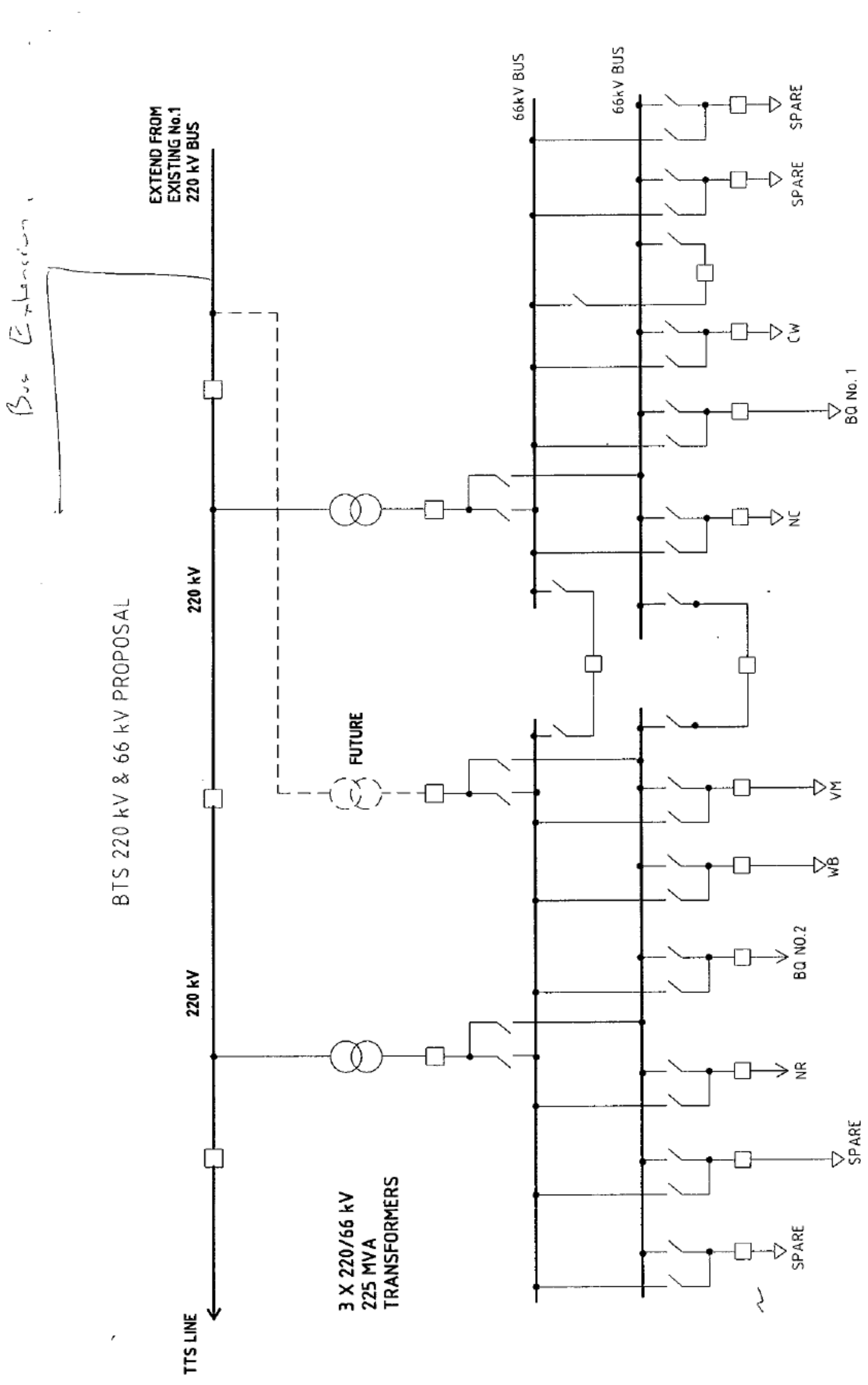
This planning estimate is not an offer, and is provided for option assessment purposes only, and should be considered as a +/- 25% figure.

Please do not hesitate to contact Nicholas Barclay (ph 03 96956737) if you wish to further explore this CBD augmentation option.

Yours sincerely,

Norm Drew
General Manager Transmission Network Development


BTS 220 kV & 66 kV PROPOSAL
EXTEND FROM
EXISTING No.1
220 kV BUS
Bus Extension
66kV BUS
66kV BUS
SPARE
SPARE
CW
BQ No. 1
NC
220 kV
FUTURE
VM
WB
BQ NO.2
220 kV
NR
SPARE
SPARE
3 X 220/66 kV
225 MVA
TRANSFORMERS
TTS LINE

APPENDIX J. ECONOMIC BENEFITS OF CBD SECURITY ENHANCEMENT

SINCLAIR KNIGHT MERZ
SKM

Economic Benefits of CBD Security Enhancement

CBD SECURITY ENHANCEMENT

- UPDATED
- 4 August 2006

Economic Benefits of CBD Security Enhancement

CBD SECURITY ENHANCEMENT

- UPDATED
- 4 August 2006

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Contents

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3	4 March 2005	CitiPower			
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EXECUTIVE SUMMARY

CitiPower has been in discussion with the ESC regarding the merits of a proposal to upgrade the security of supply standard for the CBD subtransmission network supplying the CBD. In these discussions the ESC has requested additional economic analysis of the benefits of security enhancement.

CitiPower has requested that SKM undertake an analysis to estimate the economic benefits of adopting an enhanced CBD supply security standard.

In this report, SKM has provided some background information on the costs of major network failures with particular reference to CBD supply interruptions. This information consists of cost estimates for the Melbourne CBD outages in 2001 and the costs of catastrophic outages elsewhere. It is intended that this information will provide a useful reference point in assessing: -

a) the economic risks associated with catastrophic supply failures; and

b) the need for security enhancement to the CBD electricity supply.

The analysis of these incidents highlights the significant economic costs associated with prolonged supply outages.

SKM has undertaken a probabilistic assessment of the benefits of security enhancement to the CBD network for the period 2007 to 2032. The benefits ranged from **$2.27 M** in 2011 (when benefits fully accrue) to **$7.67 M** in 2032. This number represents the probability weighted cost of Energy at Risk and provides a basis for economically evaluating and justifying the adoption of a higher security standard for the CBD. **However, it is emphasised that if a catastrophic incident were to occur, the actual costs would be many times higher than these amounts.** In addition, it is worth noting that interruptions to CBD supply result in large and widespread costs across the economy, and these costs are not fully reflected in the probability weighted cost of Energy at Risk.

Finally, in this report, SKM has set out a comparison of security standards of CBD networks both within Australia and around the world. In SKM's opinion, the CBD of Melbourne ranked second lowest on the "security of supply" scale of those cities surveyed, even though it had the highest CBD load (700MW) of those cities.

BACKGROUND

CitiPower has been in discussion with the ESC regarding the merits of a proposal to upgrade the security of supply standard for the subtransmission network supplying the CBD. The earlier SKM report titled 'CitiPower Review of CBD Security of Supply Planning Standards, Updated Final Report, 22 August 2006' provides information in support of this expenditure.

During the course of the 2006-10 Electricity Distribution Price Review, the ESC requested additional economic analysis of the benefits of security enhancement.

CitiPower has requested that SKM undertake an analysis to examine and evaluate the economic benefits of adopting an enhanced CBD supply security standard.

METHODOLOGY

Assessing the economic implications of enhancement to security of supply is not a trivial task. In this report, SKM has used four different approaches to estimate the economic costs and risks associated with the present level of CBD supply security, and to estimate the benefits of adopting an enhanced CBD security standard.

The first approach is to evaluate the cost of the two CBD incidents referred to in SKM's earlier report. The evaluation assesses the actual costs incurred (given the existing CBD network configuration) as well as the likely costs of such incidents for the CBD network designed to an enhanced security standard. This assessment would illustrate the benefits of adopting an enhanced security standard, with reference to two actual cases.

The second approach is to carry out an analysis of Energy not Served. This would entail a probabilistic assessment of the impact of outages on loss of load using the CBD network configuration as it now stands and for the security enhanced network. This would provide a MINIMUM estimate of the economic impact of security enhancement.

The third approach is to refer to published literature and obtain an understanding of the costs of large-scale energy supply interruptions in other developed economies around the world. As part of this approach, SKM would also draw on published reports relating to the economic impact of the 1998 Auckland CBD incident and the ESSO-Longford incident in Victoria.

The fourth approach is to provide a comparison of the Melbourne CBD security of supply standards with those of other CBDs both within Australia and around the world.

SECURITY ENHANCED NETWORK

The SKM report "Review of CBD Security of Supply and Planning Standards - Updated Final Report, 22 August 2006" analysed two incidents that resulted in loss of supply to the Melbourne CBD. The key conclusion drawn from the analysis (set out in section 3.5.2 of that report) was as follows:

> "Had the CBD network been designed to higher security standards (eg "N-1 Secure"), the CBD outages of 2nd January and 9th November could have been either avoided or reduced in severity. In both events, the prior outages took place a number of days before the loss of supply occurred. In other words, the CBD network was left in a "satisfactory operating state"[33] for a significant period. Had the CitiPower CBD network been returned to a "secure operating state"[34] after each of the planned outages, it would have been in a position to cope with the subsequent forced outages. To achieve this outcome (ie achieve a higher security standard) would have required installation of 66kV circuit breakers at Zone Substations and 66kV ties between Terminal Stations."

The term "N-1 Secure" is defined by SKM as follows:

> "The network can withstand the loss of any element and maintain supply to all customers. In addition the network can be subsequently re-configured to withstand a further outage. During the time taken to re-configure - which is targeted to be 30 minutes, there is a risk of supply interruption if a second contingency occurs.."

From this definition is clear that the "N-1 Secure" security standard is not the same as a true "N-2" security standard. The aim of the "N-1 Secure" security standard is to limit the extent and cost of an outage, not necessarily to eliminate the risk of an outage. It should be noted that even with "N-2" security standard there is still a risk of supply failure, as seen by the 1998 Auckland incident.

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[33] "Satisfactory Operating State" is a term used in the National Electricity Rules (NER) to describe a power system that is able to provide electricity in a stable manner and within the prescribed technical envelope (voltage, frequency, fault levels, ratings, etc). However, when a system operates in this state, load may be interrupted if a network outage occurs.

[34] "Secure Operating State" means as for "Satisfactory Operating State" but with the addition of a capability to withstand the occurrence of a single credible contingency and to return to a "Satisfactory Operating State" in accordance with the power system security and reliability standards set out in the NER. Such a system is considered to have a security standard of (N-1).

SKM believes that an “N-1 Secure” security standard is a cost-effective means of limiting the risk and impact of a catastrophic incident.

In the Melbourne CBD, upgrading to the “N-1 Secure” standard involves:

- installing switching for selected Zone substations;
- installing switching for selected 66kV cables;
- installing 66kV ties between Terminal Stations.;
- installing additional 66kV cables between selected Zone substations.

COST OF RECENT CBD OUTAGES

Event on 9th November 2001

Summary of Event

SPI PowerNet was installing a 4th 220/66kV transformer at WMTS. To enable the required works to be carried out, the No 3 220/66kV transformer was taken out of service. (This transformer was out of service for several days prior to the event.) As a result of a secondary control scheme failing to operate correctly the No 2 220/66kv transformer was disconnected, leaving the entire 66kV load being supplied by a single transformer. This transformer then tripped on overload, resulting in loss of supply to over 82,000 customers (total for both CitiPower and AGL). As WMTS supplies 50% of the CBD, it is estimated that a further 130,000 people in the CBD were directly affected by the event.

Cost of Event based on Lost Load

WMTS load at time of interruption = 460MW

(CBD Component = 345MW approx)

Outage duration = 30 minutes

Total Energy lost = 460MW for 30minutes (estimated) for both CitiPower and AGL

CBD Component = 345MW for 30 minutes = 172.5MWh

Value of Customer Reliability (VCR) = $61,388/MWhr for CBD (based on Commercial Sector VCR)

Cost of Outage to customers = $10.59M (CitiPower's CBD component only)

Event on 2nd January 2001

Summary of Event

On the weekend of 31 December 2000, a 66kV feeder from WMTS to Zone substation JA was taken out of service due to a low-pressure oil alarm. Supply to VM was maintained by the WMTS-VM2 66kV feeder. WMTS-VM3 66kV feeder was used to provide a second source of supply. Due to an unexpected increase in load, protection relays tripped on overload. The relay failed to indicate that overloading was the cause of tripping. Subsequent switching to restore supply resulted in an overload of a section of the remaining 66kV circuit to JA (WMTS-VM3 via sub W). This overloading exacerbated the condition of a cable that had been damaged at some undetermined time in the past, resulting in a trip and subsequent loss of supply to part of the CBD. Approximately 12,200 customers were affected for an average of 30 minutes.

Cost of Event based on Lost Load

Sub JA load at time of interruption = 60MW (estimated)

Outage duration = 1 hour

Energy Lost = 60 MW for 1 hour = 60MWh

VCR = $61,388/MWhr

Cost of Outage to customers = $3.68M

Discussion

The cost analysis of the two incidents demonstrates the large costs associated with CBD outages - even of a comparatively short duration.

SKM would argue that the true community cost is much larger than shown because of the impact on the general commercial activity and the large number of daily visitors to the CBD. Table 1 below highlights this aspect.

Table 13 People in CBD on a Daily Basis 2003

Category	CBD daily population
Employed in CBD **	180,000
National and International Visitors ##	90-95,000
Metropolitan and Country Victorian Visitors ##	161,000 – 200,000
Residential ##	20,000
Total Daily Population of CBD	**451,000 – 495,000**

Sources ** Bureau of Statistics

Sustainable City Research Department, City of Melbourne

The **Total Daily Population of the CBD** (say 475,000) can be compared to the number of **customers** affected by the 2nd January failure (approximately 12,200).

The table above also provides data on the number of visitors to the CBD. It seems reasonable to assume that a large percentage of the national and international visitors would change their plans if the CBD were facing a prolonged supply restriction. This would have flow-on effects in terms of lost business and on employment, particularly in the hospitality and services sectors. These flow-on effects are not fully captured in the VCR figure of $61,388 per MWh of unserved energy.

PROBABILITY OF CBD OUTAGES

Probability Assessment

A probabilistic assessment of the impact of outages on loss of load has been performed. The assessment was made for the CBD network configuration as it now stands and also for the security-enhanced network. In essence, the analysis considered the probability of a major failure resulting in loss of one transformer at a Zone substation. The probability of a major failure resulting in loss of a second transformer during the outage interval of the first failed transformer was then calculated. This provided a probability of coincident loss of two transformers resulting in loss of supply.

CitiPower provided plant outage rates and repair times that form key inputs into the probabilistic analysis. SKM reviewed this data and found that the CitiPower data was in accord with published figures and other data from Australian distribution businesses.

The assessment was carried out for each of the CBD Zone Substations and considered only major failures with equipment outage durations of 8-10 weeks. The failure rates and repair times of the various plant items were obtained from CitiPower and are listed below.

Item	Failure Rate	Mean Outage Duration
Zone Sub Transformer	0.5% major outages /year	10 weeks
66kV Cable	3 faults/100km/year	8 weeks

SKM's analysis has ignored the impact of overhead line faults and faults on cables that could be isolated in a reasonably short timeframe (approx 1 hr). These outages will result in only a limited loss of supply. This simplified the analysis and ensured that the results are likely to be understated rather than overstated.

In estimating the load at risk for Zone substation incidents, it has been assumed that there was 15MVA of permanent load transfer available and that the remaining transformer was loaded to its cyclic rating. This approach was taken to ensure the probabilistic analysis reflected the likely actual operating scenario after a major outage.

For Terminal Station incidents, it has been assumed that there is no transfer capability and the remaining transformers can be loaded to their summer cyclic rating.

Expected Annual Benefit of CBD Security Enhancement

The probabilistic assessment of CBD load at risk has been carried out using the forecast loads for the period 2006 to 2036 and the existing network arrangements. In addition, an assessment has been made of the load at risk after the proposed security enhancement works. Details of the probabilistic assessment for each Zone substation are provided in the Appendices and are summarised below.

The results for the period 2006-2012 only are shown here for clarity, given that from 2012 the full annual benefits of the security enhancement works will be delivered (since the study assumes that the works will be completed and commissioned by then). From 2012, the annual benefits of security enhancement (in real dollar terms) continue to increase as a function of demand growth.

The results for the full 25-year assessment are provided in Section 7 and full tables of results are shown in Appendix D.

Improved Switching for Zone Substations

The table below summarises the net benefits associated with security enhancement for Zone Substations. The results are based on outages that result in loss of two transformers at a substation.

It has been assumed that 75% of the benefits of the security enhancement works commences in 2011 with 100% of the benefits accruing in 2012.

In arriving at these results, it has been assumed that the remaining transformer is loaded to its summer cyclic rating and that there is 15MVA of load transfer available in each case.

Case	2010	2011	2012	2013	2014	2015	2016
Existing CBD Network - cost of coincident outages	**$0**	**$1,930**	**$2,716**	**$2,874**	**$3,037**	**$3,201**	**$3,373**
Security Enhanced CBD Network – cost of coincident outages	$0	$58	$60	$62	$63	$65	$66
Net Benefit of Security Enhancement ($K)	**$0**	**$1,872**	**$2,656**	**$2,813**	**$2,974**	**$3,136**	**$3,307**

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In essence, the security-enhanced case for Zone substations provides for improved 66kV switching at several Zone substations and a number of additional 66kV circuits. There is still a small risk of two transformers at a given Zone substation having coincident failures resulting in loss of supply. However the expected cost associated with this low probability event is only 2.8% ($57K versus $2.0M) of the situation as it currently stands.

A summary of benefits for the 25-year period 2006-2036 is provided in Appendix D.

Multiple Outages associated with Sub VM

The analysis in Section 6.2.1 was based around assessing the probability of multiple outages affecting a single zone substation. However, Sub VM has a particular configuration and location in the network that requires a more detailed examination.

Outage of any two 66kV feeders between West Melbourne Terminal Station and Sub VM will result in multiple loss of transformers at a number of Zone Substations. Such outages will result in a much-increased level of load at risk. A probabilistic assessment for each combination of WMTS-VM 66kV feeder outages has been made with the details provided in Appendix B. With such outages, there will be no transfer capacity between substations and this has been factored into the analysis.

The table below provides a summary of the expected costs associated with multiple zone substation outages arising from various combinations of WMTS-VM 66kV cable failures. These benefits are in addition to the benefits described in section 6.2.1.

Expected Cost of Load at Risk ($K)

Cable Outages	Load at Risk (in addition to VM)	2010	2011	2012	2013	2014	2015	2016
VM1 and VM3 outage	LQ and WA		$ 157.0	$ 215.9	$ 224.2	$ 232.7	$ 241.4	$ 250.4
VM1 and VM2 outage	WA		$ 21.1	$ 28.8	$ 29.7	$ 30.7	$ 31.6	$ 32.6
VM2 and VM3 outage	WA		$ 69.4	$ 94.7	$ 97.7	$ 100.7	$ 103.9	$ 107.1
Net Impact of Multiple Outages ($K)		$ -	$ 247.6	$ 339.4	$ 351.6	$ 364.1	$ 376.9	$ 390.1

A summary of benefits for the 25-year period 2006-2036 is provided in Appendix D.

Improved Transfer Capability between Terminal Stations

The benefits arising from improved transfer capability between Terminal Stations have been based on a coincident major failure of two transformers at a Terminal Station (WMTS or RTS). These benefits are in addition to the benefits described in sections 6.2.1 and 6.2.2.

While the coincident major failure of two transformers is a rare event, the amount of load at risk is significant. The analysis has assumed that the security enhancement will allow load restoration within 1 hour by means of remote switching capability. Thus, the impact of a (rare) double transformer outage can be limited by transferring load between Terminal Stations equal to the capacity of at least one transformer.

Benefits of Transfers between Terminal Stations ($K)

	2009	2010	2011	2012	2013	2014	2015	2016
RTS Transfer Benerfits	$70.1	$73.5	$77.0	$80.5	$84.0	$87.5	$91.1	$ 95.74
WMTS Transfer Benefits	$48.2	$52.2	$56.4	$60.6	$64.9	$69.4	$73.8	$ 78.06
Expected Total Benefit	$118.3	$125.8	$133.4	$141.2	$149.0	$156.9	$164.9	$ 173.8
Cost of 1 hour outage to arrange transfer	$0.6	$0.6	$0.7	$0.7	$0.7	$0.8	$0.8	$ 0.86
Net Benefit ($K)	$117.7	$125.1	$132.8	$140.5	$148.2	$156.1	$164.1	$ 172.93

A summary of benefits for the 25-year period 2006-2036 is provided in Appendix D.

Total Benefit of Security Enhancement ($K)

The total benefits for security enhancement (for Zone Substations, Cables, Multiple Outages with VM, and Terminal Stations) for each year from 2006 to 2012 has been estimated as follows:

Overall Summary of Benefits arising from Security Enhancement of CBD

	2009	2010	2011	2012	2013	2014	2015	2016
Zone Sub - 1tf	$0	$0	$1,886	$2,656	$2,813	$2,974	$3,136	$3,307
VM - Multiple Outages	$0	$0	$248	$339	$352	$364	$377	$390
Terminal Stations	$118	$125	$133	$140	$148	$156	$164	$173
Net Benefit ($K)	**$118**	**$125**	**$2,267**	**$3,136**	**$3,312**	**$3,494**	**$3,677**	**$3,870**

The complete summary of results for the 25-year period 2006-2036 is provided in Appendix D.

Note that benefits commence at different times depending on the nature of the security enhancement works completed over the period to 2012.

Discussion

The total benefit of Security Enhancement to the CBD is shown to increase from **$2.27M** in 2011(when 100% of all benefits accrue) to **$3.87M** in 2016. (Some benefits relating to Terminal Station transfers commence before this time). This number represents the probability-weighted benefit based on an estimate of actual load at risk using a value of customer reliability (VCR) appropriate for the CBD (ie $61,388/MWhr). The trend shown by these results continues out as shown in the results for the full 25-year analysis. In 2032, the overall benefits due to the Security Enhancement works rise to **$7.67M** in real terms.

EXPERIENCE OF CATASTROPHIC INCIDENTS

Auckland

On 20th February 1998, the City of Auckland in New Zealand had a number of 110kV cable failures resulting in total loss of supply to the CBD. Auckland has a population of around 1 million, many of whom were affected.

Power shortages in the CBD continued for more than 2 months (on a rotating interruption basis). The incident crippled businesses in the CBD and resulted in estimated costs to the community of A$75 million[35].

An interesting finding of the Ministerial Inquiry[36] into the incident with regard to network planning was:

> "An appropriate level of redundancy was factored into the CBD supply network planning – an n-2 contingency plan was partially adopted and this was appropriate for the CBD".

Esso Longford

The following excerpt has been taken from Parliament of Australia research papers[37]

> "The explosion at the Longford Esso/BHP gas processing facility near Sale on September 25, 1998 disrupted the entire Victorian gas supply. Gas supply was restored on 5th October 1998, in the first instance to industry and business facilities and to domestic users in the following days.
>
> The gas disruption had a major impact on Victorian industry and the broader economy. A number of reports have suggested the disruption has cost Victorian business about $1.3 billion as well as the massive inconvenience to householders. Victorian industries which had lost their energy source were forced to close and in addition component manufacturers and suppliers to the Victorian industry in other States also had to close as there was no demand for their products during this period."

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[35] Time International 1998, Donmoyer RJ "Darkness Down Under. Major Power Outage Enters Second Month in Auckland New Zealand" 1998

[36] Ministerial Inquiry into the Auckland Power Supply Failure, June 1998

[37] Parliament of Australia, Parliamentary Library. Research Paper 5 1998-1999 "Natural Gas: Energy for the New Millennium" Mike Roarty December 1998

New York

On 14th August 2003, there was a widespread blackout across USA and Canada affecting more than 50 million people and interrupting 61,800MW of load. The major part of the load was restored within 32 hours but final restoration took 72 hours in total.

The impact on New York CBD (population 8.1 million) was severe with outages in excess of 18 hours and loss of approximately 103,000 MWh. Anderson Economic Group (AEG) estimated lost earnings in New York of US$1.98 billion[38].

In addition AEG quoted the New York City's comptrollers office "estimated that losses topped $1 billion, including $800 million in gross city product. The figure includes $250 million in frozen and perishable food that had to be dumped. The Restaurant Association calculated that the City's 22,000 restaurants lost between $75 and $100 million in wasted food and lost business. …New York City's mayor estimated that the city would pay almost $10 million in overtime related to the outage."

CREIPI[39] also assessed the impact of the blackout using a sector-analysis approach. They found that the impact of the blackout increased as the duration extended. For example, in the services sector, an outage of less than 30 minutes duration cost each customer around US$10,000, while an outage of one day or over cost each customer around US$40,000.

Discussion

The catastrophic incidents described above are just a few that have occurred around the world. The key lessons to be learnt from these examples are:

- Although widespread catastrophic failures of power systems are rare, they do occur;
- When such widespread incidents occur, they are extremely expensive to the community with significant flow-on effects that are difficult to quantify.

[38] Anderson, Patrick L and Ilhan K,Geckil "Northeast Blackout Likely to Reduce US Earnings by $6.4 Billion," AEG Working Paper 2003-2, August 19, 2003

[39] Central Research Institute of Electric Power Industry, Japan CRIEPI News 398 "Impact of North American Blackout" Toshio Ariu

SECURITY STANDARDS OF OTHER CBDS

National/International Comparisons

SKM has conducted a number of assignments involving the review of Security of Supply standards to the CBDs of major international cities. Some of these studies have been associated with the "optimisation" phase of ODRC valuation assignments while others have been specific security and reliability of supply studies. These studies have given SKM an unequalled insight into the different system planning philosophies, network configurations, operational practices and comparative performance of systems supplying major CBD's, including:

- Melbourne
- Sydney
- Brisbane
- Adelaide
- Wellington
- Auckland
- Singapore
- Glasgow
- Johannesburg
- Cape Town
- Hobart
- and others

In undertaking these studies, SKM has also become familiar with a number of international Standards and Guidelines, including:

- National Electricity Rules (Australia)
- Victorian Distribution Code (Victoria)
- EEA Guidelines (New Zealand)
- Engineering Recommendations P2/5 (UK)
- North American Electricity Reliability Council Planning Standards (US)

Interestingly, most international system security and planning standards (including Australia's National Electricity Rules) are written around the security of supply of transmission systems generally, not the security of supply to CBDs specifically.

In 2003, SKM conducted a confidential survey of eight (8) national and international cities which could be considered, by the nature of their population, electrical loading and business activities to be "similar". These cities all had CBDs with electrical loading of between 200MW and 700MW(Melbourne). The electricity systems supplying these cities were then ranked from "most secure" to "least secure" on the basis of their current documented security criteria, and on the actual compliance with that criteria as represented by an assessment of the load (MW) at risk under specified N-1 contingency conditions.

The CBD of Melbourne ranked second lowest on the "security of supply" scale of those cities surveyed, even though it had the highest CBD load (700MW) of those cities.

Security of Supply to Sydney

Historically, the security of supply to Sydney CBD and surrounding suburbs has been planned to a criterion substantially higher than N-1, with a probabilistic approach being adopted during the late 1980s and 1990s. Following the Auckland blackouts in 1998, TransGrid and EnergyAustralia jointly adopted a "modified N-2" standard which is less onerous than "N-2" in that it provides for loss of an existing 330kV cable and one of the critical 132kV system elements supplying the CBD.

The adoption of a "modified N-2" criterion resulted in Transgrid and Energy Australia proceeding with the Haymarket 330/132kV project. While there is considerable debate about the final cost of this project versus its original approved cost, there is general agreement by the parties that the enhancement to a "modified N-2" criteria was appropriate. It is interesting to note that a consultant's report to the ACCC[40] observed that:

> "The choice of the planning standard to apply in TransGrid and EnergyAustralia's networks is a matter to be regulated by the government of New South Wales, not the ACCC. In our view it is therefore inappropriate for the Commission to take a view on the planning standard adopted by Transgrid."

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40 "An assessment of the prudency of TransGrid's investment in the MetroGrid project - A report to the ACCC" Mountain Associates 14 April 2004 Section 4.1

Security of Supply to Brisbane

Historically (since the early 1990s), the transmission (110kV) and subtransmission (33kV) systems supplying the CBD of Brisbane have been designed under Energex's Reliability Assessment Planning (RAP) Guidelines, which generally accept a certain probability of the risk of loss of supply, and weigh that probability and its consequences against the capital cost of augmenting the system to mitigate against the loss of supply. While not specifically stated under Energex's RAP Guidelines, it is understood that these guidelines were applied uniformly across Energex's system, including the CBD of Brisbane.

After severe electrical storms during the summer of 2003/04, and subsequent widespread blackouts on the Energex system (not necessarily the CBD), the Queensland Government initiated an inquiry into the reliability of supply of both Energex and Ergon Energy.

The subsequent report, known as the Somerville Report (or Electricity Distribution and Service Delivery Report – EDSDR) made a total of 44 recommendations. While none of the 44 recommendations specifically addressed security of supply to the CBD, there were a number of recommendations which addressed overall issues of system planning criteria and supply reliability. The key recommendation in this regard was:

> "Energex be required to maintain "N-1" on all bulk supply sub-stations, zone supply sub-stations, and sub-transmission feeders. Critical high voltage feeders should also meet "N-1" with the exception of those where Energex can provide satisfactory evidence that this does not put significant numbers of customers at risk. Where Energex chooses to use interconnection to provide "N-1" capacity for single transformer bulk or zone supply sub-stations, it should be required to demonstrate that there is adequate transfer capability to meet "N-1" in a timely manner."

As mentioned earlier, no specific recommendation was made in the Somerville Report about the security or reliability of supply to the Brisbane CBD. However, the general recommendations amount to an increased security of supply standard to the Brisbane CBD network.

Security Requirements under the National Electricity Rules

The National Electricity Rules (section 4.2.6) require "N-1 secure" supply for the interconnected transmission system as a whole. That is, the system should be able to withstand any single worst case contingency, and be capable of being returned to a secure state within 30 minutes of a contingency. In effect this requirement translates into a criterion which SKM would term “N-1 secure”. “N-1 secure” is more onerous than “N-1”, but less onerous than “N-2”.

SKM believes that security criteria at the upper end of the range specified in the Rules should apply to the Melbourne CBD. The justification for this lies in the importance of reliable supply to CBD customers and the requirement of S5.1.2.2 of the Rules that the size and importance of customer groups are taken into account when selecting the appropriate level of supply security.

SUMMARY AND CONCLUSIONS

The issue of economic justification of security enhancements to a CBD supply is difficult to address. Power systems have a considerable degree of redundancy built into them and as a result, catastrophic failures resulting in widespread and prolonged outages are rare.

In this report, SKM has provided some background information on the costs of major network failures with particular reference to CBD supply interruptions. This information consisted of cost estimates for the Melbourne CBD outages in 2001 and costs for catastrophic outages elsewhere. It is hoped that this information will provide a useful reference point in assessing: -

c) the economic costs and risks associated with catastrophic outages; and

d) the need for security enhancement to the CBD electricity supply.

The analysis of these previous incidents highlights the significant economic costs associated with prolonged supply outages.

SKM has undertaken a probabilistic assessment of the benefits of security enhancement to the CBD network for the period 2009 to 2032. The total benefit of Security Enhancement to the CBD is shown to increase from **$2.27M** in 2011(when 100% of all benefits accrue) to **$3.87M** (in real terms) in 2016. Some benefits relating to Terminal Station transfers commence before this time. This number represents the probability-weighted (or "expected") value of the benefit based on an estimate of actual load at risk using a value of customer reliability (VCR) appropriate for the CBD (ie $61,388/MWhr). The magnitude of the annual benefit increases as a function of forecast lead growth for the full 25-year analysis. In 2032, the expected benefits due to the security enhancement works rise to **$7.67M** in real terms.

These data provide the basis for economically evaluating the costs and benefits of providing security enhancement to the CBD. It is emphasised, however, that if a catastrophic incident were to occur, the costs would be many times the expected value amounts estimated in this paper. In addition, it is noted that the expected values of benefits estimated in this paper reflect the Value of Customer Reliability (VCR) only. Interruptions to CBD supply result in large and widespread costs across the economy, and these costs are not fully reflected in the VCR.

Finally, SKM has provided a discussion comparing security standards of CBD networks both within Australia and around the world. In SKM's opinion, the CBD of Melbourne ranked second lowest on the "security of supply" scale of those cities surveyed, even though it had the highest CBD load (700MW) of those cities.

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Appendix A Probabilistic Assessment for Zone Substation Security Enhancement

A.1 Sub WA

WA		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Load Forecasts	Summer MW	0.0	69.3	70.9	72.1	73.4	74.7	76.0	77.9	79.9	81.9	83.9
	Summer MVA	0.0	73.7	75.4	76.7	78.1	79.5	80.9	82.9	85.0	87.1	89.3
	Summer pf	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
High Scenario Adjustment	1.08											
Peak Load (MVA)		0.00	79.60	81.43	82.84	84.35	85.86	87.37	89.56	91.80	94.09	96.44
Available Load Transfer (MVA)		15	15	15	15	15	15	15	15	15	15	15
Cyclic Rating of 1 transformer (MVA)		33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
Load Shed (MVA)		-48.50	31.10	32.93	34.34	35.85	37.36	38.87	41.06	43.30	45.59	47.94
Load Factor		0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
Power Factor		0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
Load Shed (MW)		0.00	27.41	29.03	30.27	31.60	32.93	34.26	36.19	38.16	40.19	42.26
VCR ($/MWhr)	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
Prob of Coincident failures		0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814
Hours at Risk		202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
WA Expected Outage Cost ($)		$ -	$ 266,000	$ 282,000	$ 294,000	$ 307,000	$ 320,000	$ 333,000	$ 352,000	$ 371,000	$ 390,000	$ 411,000

2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
86.0	88.2	90.4	92.7	95.0	97.3	99.8	102.3	104.8	107.5	110.1	112.9	115.7	118.6	121.6	124.6
91.5	93.8	96.2	98.6	101.0	103.6	106.1	108.8	111.5	114.3	117.2	120.1	123.1	126.2	129.3	132.6
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
98.85	101.32	103.86	106.45	109.12	111.84	114.64	117.51	120.44	123.45	126.54	129.70	132.95	136.27	139.68	143.17
15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
50.35	52.82	55.36	57.95	60.62	63.34	66.14	69.01	71.94	74.95	78.04	81.20	84.45	87.77	91.18	94.67
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
44.39	46.56	48.80	51.09	53.43	55.84	58.30	60.83	63.42	66.07	68.79	71.58	74.44	77.37	80.37	83.45
$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814	0.0007814
202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
$ 431,000	**$ 452,000**	**$ 474,000**	**$ 496,000**	**$ 519,000**	**$ 542,000**	**$ 566,000**	**$ 591,000**	**$ 616,000**	**$ 642,000**	**$ 668,000**	**$ 695,000**	**$ 723,000**	**$ 752,000**	**$ 781,000**	**$ 811,000**

A.2 Sub VM

VM		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Load Forecasts	Summer MW	0.0	67.4	71.7	74.3	76.7	79.3	81.8	83.9	86.0	88.1	90.3
	Summer MVA	0.0	74.9	79.7	82.5	85.2	88.1	90.9	93.2	95.5	97.9	100.3
	Summer pf	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
High Scenario Adjustment	1.08											
Peak Load (MVA)		0.00	80.89	86.08	89.10	92.02	95.15	98.17	100.63	103.14	105.72	108.36
Available Load Transfer (MVA)		15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Cyclic Rating of 1 transformer (MVA)		31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
Load Shed (MVA)		-46.60	34.29	39.48	42.50	45.42	48.55	51.57	54.03	56.54	59.12	61.76
Load Factor		0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
Power Factor		0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
Load Shed (MW)		-39.33	28.94	33.32	35.87	38.33	40.97	43.52	45.60	47.72	49.90	52.13
VCR ($/MWhr)	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
Prob of Coincident failures		0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090
Hours at Risk		202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
VM Expected Outage Cost ($)		-$ 533,000	$ 392,000	$ 452,000	$ 486,000	$ 520,000	$ 555,000	$ 590,000	$ 618,000	$ 647,000	$ 676,000	$ 707,000

2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
92.6	94.9	97.2	99.7	102.2	104.7	107.3	110.0	112.8	115.6	118.5	121.4	124.5	127.6	130.8	134.1
102.8	105.4	108.1	110.8	113.5	116.4	119.3	122.3	125.3	128.4	131.7	134.9	138.3	141.8	145.3	149.0
0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
111.07	113.85	116.70	119.61	122.60	125.67	128.81	132.03	135.33	138.71	142.18	145.74	149.38	153.11	156.94	160.87
15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
64.47	67.25	70.10	73.01	76.00	79.07	82.21	85.43	88.73	92.11	95.58	99.14	102.78	106.51	110.34	114.27
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
54.41	56.76	59.16	61.62	64.14	66.73	69.38	72.10	74.89	77.74	80.67	83.67	86.74	89.89	93.13	96.44
$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090	0.001090
202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
$ 738,000	**$ 769,000**	**$ 802,000**	**$ 835,000**	**$ 869,000**	**$ 905,000**	**$ 940,000**	**$ 977,000**	**$ 1,015,000**	**$ 1,054,000**	**$ 1,093,000**	**$ 1,134,000**	**$ 1,176,000**	**$ 1,218,000**	**$ 1,262,000**	**$ 1,307,000**

SKM

A.3 Sub LQ

LQ		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	201
Load Forecasts	**Summer MW**	0.0	120.4	123.0	125.8	128.5	131.3	134.1	137.5	140.9	144.5	148.
	Summer MVA	0.0	128.1	130.9	133.8	136.7	139.7	142.7	146.3	149.9	153.7	157.
	Summer pf	0.940	0.94	0.94	0.94	0.94	0.94	0.94	0.940	0.940	0.940	0.94
High Scenario Adjustment	**1.08**											
Peak Load (MVA)		0.00	138.35	141.37	144.50	147.64	150.88	154.12	157.97	161.92	165.97	170.1
Available Load Transfer (MVA)		15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.00
Cyclic Rating of 1 transformer (MVA)		65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9
Load Shed (MVA)			57.45	60.47	63.60	66.74	69.98	73.22	77.07	81.02	85.07	89.2
Load Factor		0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.93
Power Factor		0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.94
Load Shed (MW)		0.00	50.64	53.30	56.07	58.83	61.68	64.54	67.93	71.42	74.98	78.6
VCR ($/MWhr)	**$ 61,388**	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 6
Prob of Coincident failures		0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007
Hours at Risk		202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.
LQ Expected Outage Cost ($)			**$ 441,000**	**$ 465,000**	**$ 489,000**	**$ 513,000**	**$ 538,000**	**$ 563,000**	**$ 592,000**	**$ 623,000**	**$ 654,000**	**$ 68**

2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
151.8	155.6	159.4	163.4	167.5	171.7	176.0	180.4	184.9	189.5	194.3	199.1	204.1	209.2	214.4	219.8
161.5	165.5	169.6	173.9	178.2	182.7	187.2	191.9	196.7	201.6	206.7	211.8	217.1	222.6	228.1	233.8
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
174.37	178.73	183.20	187.78	192.47	197.28	202.21	207.27	212.45	217.76	223.21	228.79	234.51	240.37	246.38	252.54
15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9
93.47	97.83	102.30	106.88	111.57	116.38	121.31	126.37	131.55	136.86	142.31	147.89	153.61	159.47	165.48	171.64
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
82.39	86.23	90.17	94.21	98.35	102.59	106.93	111.39	115.96	120.64	125.44	130.36	135.40	140.57	145.86	151.29
$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012	0.0007012
202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
$ 718,000	**$ 752,000**	**$ 786,000**	**$ 821,000**	**$ 857,000**	**$ 894,000**	**$ 932,000**	**$ 971,000**	**$ 1,011,000**	**$ 1,052,000**	**$ 1,093,000**	**$ 1,136,000**	**$ 1,180,000**	**$ 1,225,000**	**$ 1,271,000**	**$ 1,319,000**

SKM

A.4 Sub MP

MP		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Load Forecasts	Summer MW	0.0	103.6	106.0	108.3	110.6	113.0	115.3	118.2	121.2	124.2	127.3	130.5
	Summer MVA	0.0	120.5	123.2	125.9	128.6	131.4	134.1	137.5	140.9	144.4	148.0	151.7
	Summer pf	0.860	0.86	0.86	0.86	0.86	0.86	0.86	0.860	0.860	0.860	0.860	0.860
High Scenario Adjustment	1.08												
Peak Load (MVA)		0.00	130.14	133.06	135.97	138.89	141.91	144.83	148.45	152.16	155.96	159.86	163.86
Available Load Transfer (MVA)		15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Cyclic Rating of 1 transformer (MVA)		58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4
Load Shed (MVA)			56.74	59.66	62.57	65.49	68.51	71.43	75.05	78.76	82.56	86.46	90.46
Load Factor		0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
Power Factor		0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860
Load Shed (MW)		0.00	45.76	48.11	50.46	52.81	55.25	57.60	60.52	63.52	66.58	69.73	72.95
VCR ($/MWhr)	$ 61,388												
Prob of Coincident failures		0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517
Hours at Risk			0	0	0	0	0	0	0	0	0	0	0
MP Expected Outage Cost ($)		**$ -**	**$ 257,000**	**$ 270,000**	**$ 283,000**	**$ 297,000**	**$ 310,000**	**$ 323,000**	**$ 340,000**	**$ 357,000**	**$ 374,000**	**$ 392,000**	**$ 410,000**

2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
133.7	137.1	140.5	144.0	147.6	151.3	155.1	159.0	163.0	167.0	171.2	175.5	179.9	184.4	189.0
155.5	159.4	163.4	167.5	171.7	176.0	180.3	184.9	189.5	194.2	199.1	204.0	209.2	214.4	219.7
0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860
167.96	172.15	176.46	180.87	185.39	190.03	194.78	199.65	204.64	209.75	215.00	220.37	225.88	231.53	237.32
15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4
94.56	98.75	103.06	107.47	111.99	116.63	121.38	126.25	131.24	136.35	141.60	146.97	152.48	158.13	163.92
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860
76.26	79.64	83.11	86.67	90.32	94.05	97.89	101.81	105.84	109.96	114.19	118.53	122.97	127.52	132.19
0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517	0.0004517
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$ 428,000	**$ 447,000**	**$ 467,000**	**$ 487,000**	**$ 507,000**	**$ 528,000**	**$ 550,000**	**$ 572,000**	**$ 594,000**	**$ 617,000**	**$ 641,000**	**$ 666,000**	**$ 691,000**	**$ 716,000**	**$ 742,000**

A.5 Sub FR

FR		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Load Forecasts	Summer MW	0.0	54.2	55.3	56.5	57.8	59.1	60.4	61.9	63.4	65.0	66.6	68.3
	Summer MVA	0.0	58.30	59.50	60.80	62.20	63.50	64.90	66.5	68.2	69.9	71.6	73.4
	Summer pf	0.930	0.93	0.93	0.93	0.93	0.93	0.93	0.930	0.930	0.930	0.930	0.930
High Scenario Adjustment	1.08												
Peak Load (MVA)		0.00	62.96	64.26	65.66	67.18	68.58	70.09	71.84	73.64	75.48	77.37	79.30
Available Load Transfer (MVA)		15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Cyclic Rating of 1 transformer (MVA)		30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7
Load Shed (MVA)			17.26	18.56	19.96	21.48	22.88	24.39	26.14	27.94	29.78	31.67	33.60
Load Factor		0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
Power Factor		0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930
Load Shed (MW)			15.06	16.19	17.41	18.73	19.95	21.27	22.80	24.37	25.97	27.62	29.30
VCR ($/MWhr)	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
Prob of Coincident failures		0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428
Hours at Risk		202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
FR Expected Outage Cost ($)		**$ -**	**$ 642,000**	**$ 690,000**	**$ 742,000**	**$ 798,000**	**$ 850,000**	**$ 907,000**	**$ 972,000**	**$ 1,039,000**	**$ 1,107,000**	**$ 1,177,000**	**$ 1,249,000**

SKM

2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
70.0	71.7	73.5	75.4	77.3	79.2	81.2	83.2	85.3	87.4	89.6	91.8	94.1	96.5	98.9
75.3	77.1	79.1	81.1	83.1	85.2	87.3	89.5	91.7	94.0	96.3	98.8	101.2	103.8	106.3
0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930
81.29	83.32	85.40	87.54	89.72	91.97	94.27	96.62	99.04	101.51	104.05	106.65	109.32	112.05	114.85
15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7
35.59	37.62	39.70	41.84	44.02	46.27	48.57	50.92	53.34	55.81	58.35	60.95	63.62	66.35	69.15
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930
31.03	32.81	34.62	36.48	38.39	40.35	42.35	44.41	46.52	48.68	50.89	53.16	55.48	57.87	60.31
$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428	0.003428
202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
$ 1,323,000	**$ 1,398,000**	**$ 1,476,000**	**$ 1,555,000**	**$ 1,636,000**	**$ 1,720,000**	**$ 1,805,000**	**$ 1,893,000**	**$ 1,982,000**	**$ 2,075,000**	**$ 2,169,000**	**$ 2,266,000**	**$ 2,365,000**	**$ 2,466,000**	**$ 2,570,000**

SKM

A.6 Summary of Expected Benefits for Security Enhancement to CBD Zone Substations and Cables

Case	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Existing CBD Network - cost of coincident outages	**$0**	**$1,930**	**$2,716**	**$2,874**	**$3,037**	**$3,201**	**$3,373**	**$3,546**	**$3,724**	**$3,907**	**$4,095**	**$4,287**
Security Enhanced CBD Network – cost of coincident outages	$0	$58	$60	$62	$63	$65	$66	$68	$70	$71	$73	$75
Net Benefit of Security Enhancement ($K)	**$0**	**$1,872**	**$2,656**	**$2,813**	**$2,974**	**$3,136**	**$3,307**	**$3,478**	**$3,654**	**$3,836**	**$4,022**	**$4,212**

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
$4,484	**$4,686**	**$4,894**	**$5,107**	**$5,324**	**$5,546**	**$5,775**	**$6,011**	**$6,251**	**$6,496**	**$6,749**
$77	$79	$81	$83	$85	$87	$89	$91	$94	$96	$98
$4,407	**$4,607**	**$4,813**	**$5,024**	**$5,239**	**$5,459**	**$5,686**	**$5,920**	**$6,157**	**$6,400**	**$6,651**

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Appendix B Probabilistic Assessment Multiple VM Cable Failures

Case 1	VM1 And VM3 fail	Lose WA and LQ in addition to VM											
LQ	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Summer MW		120.4	123.0	125.8	128.5	131.3	134.1	137.5	140.9	144.5	148.1	151.8	155.6
Summer MVA		128.1	130.9	133.8	136.7	139.7	142.7	146.3	149.9	153.7	157.5	161.5	165.5
Summer pf	0.940	0.94	0.94	0.94	0.94	0.94	0.94	0.940	0.940	0.940	0.940	0.940	0.940
WA	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Summer MW		69.3	70.9	72.1	73.4	74.7	76.0	77.9	79.9	81.9	83.9	86.0	88.2
Summer MVA		73.7	75.4	76.7	78.1	79.5	80.9	82.9	85.0	87.1	89.3	91.5	93.8
Summer pf	0.940	0.94	0.94	0.94	0.94	0.94	0.94	0.940	0.940	0.940	0.940	0.940	0.940
Load at risk MVA (LQ & WA only)	0.0	201.8	206.3	210.5	214.8	219.2	223.6	229.2	234.9	240.8	246.8	253.0	259.3
High Load factor	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Load factor	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
TF Rating (MVA) 1 tf at LQ and WA	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4
Correction for VM transfer	15	15	15	15	15	15	15	15	15	15	15	15	15
Load at risk MW	0.0	117.7	122.0	126.0	130.1	134.3	138.5	143.8	149.3	154.9	160.6	166.5	172.5
VCR	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
Probability	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254
Cost	**$ -**	**$ 183,544**	**$ 190,224**	**$ 196,458**	**$ 202,841**	**$ 209,372**	**$ 215,904**	**$224,201**	**$232,706**	**$241,424**	**$250,359**	**$259,518**	**$268,906**

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
159.4	163.4	167.5	171.7	176.0	180.4	184.9	189.5	194.3	199.1	204.1	209.2	214.4	219.8
169.6	173.9	178.2	182.7	187.2	191.9	196.7	201.6	206.7	211.8	217.1	222.6	228.1	233.8
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
90.4	92.7	95.0	97.3	99.8	102.3	104.8	107.5	110.1	112.9	115.7	118.6	121.6	124.6
96.2	98.6	101.0	103.6	106.1	108.8	111.5	114.3	117.2	120.1	123.1	126.2	129.3	132.6
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940

265.8	272.4	279.2	286.2	293.4	300.7	308.2	315.9	323.8	331.9	340.2	348.7	357.5	366.4
1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.4
15	15	15	15	15	15	15	15	15	15	15	15	16	17
178.7	185.0	191.5	198.1	205.0	211.9	219.1	226.4	234.0	241.7	249.6	257.7	266.9	276.2
$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254
$278,529	**$288,392**	**$298,502**	**$308,865**	**$319,486**	**$330,373**	**$341,533**	**$352,971**	**$364,695**	**$376,713**	**$389,031**	**$ 401,656**	**$ 415,972**	**$ 430,612**

Case 2 — VM1 And VM2 fail — Lose WA (LQ switched via JA) in addition to VM

LQ	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Summer MW		120.4	123.0	125.8	128.5	131.3	134.1	137.5	140.9	144.5	148.1	151.8	155.6
Summer MVA		128.1	130.9	133.8	136.7	139.7	142.7	146.3	149.9	153.7	157.5	161.5	165.5
Summer pf	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940

WA	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Summer MW		69.3	70.9	72.1	73.4	74.7	76.0	77.9	79.9	81.9	83.9	86.0	88.2
Summer MVA		73.7	75.4	76.7	78.1	79.5	80.9	82.9	85.0	87.1	89.3	91.5	93.8
Summer pf		0.94	0.94	0.94	0.94	0.94	0.94	0.940	0.940	0.940	0.940	0.940	0.940

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Load at risk MVA (WA only)	0.0	73.7	75.4	76.7	78.1	79.5	80.9	82.9	85.0	87.1	89.3	91.5	93.8
High Load factor	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Load factor	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
TF Rating (MVA) 1 tf at WA	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
Correction for VM transfer	15	15	15	15	15	15	15	15	15	15	15	15	15
Load at risk MW	0.0	53.9	55.5	56.7	58.1	59.4	60.7	62.7	64.6	66.6	68.7	70.8	73.0
VCR	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
Probability	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077
Cost	**$ -**	**$ 25,556**	**$ 26,324**	**$ 26,912**	**$ 27,544**	**$ 28,177**	**$ 28,809**	**$ 29,723**	**$ 30,659**	**$ 31,619**	**$ 32,603**	**$ 33,612**	**$ 34,646**

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
159.4	163.4	167.5	171.7	176.0	180.4	184.9	189.5	194.3	199.1	204.1	209.2	214.4	219.8
169.6	173.9	178.2	182.7	187.2	191.9	196.7	201.6	206.7	211.8	217.1	222.6	228.1	233.8
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
90.4	92.7	95.0	97.3	99.8	102.3	104.8	107.5	110.1	112.9	115.7	118.6	121.6	124.6
96.2	98.6	101.0	103.6	106.1	108.8	111.5	114.3	117.2	120.1	123.1	126.2	129.3	132.6
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
96.2	98.6	101.0	103.6	106.1	108.8	111.5	114.3	117.2	120.1	123.1	126.2	129.3	132.6
1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
15	15	15	15	15	15	15	15	15	15	15	15	16	17
75.3	77.6	79.9	82.3	84.8	87.3	89.9	92.5	95.3	98.1	100.9	103.8	107.7	111.7
$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077	0.0077
$ 35,705	**$ 36,791**	**$ 37,904**	**$ 39,046**	**$ 40,215**	**$ 41,414**	**$ 42,643**	**$ 43,902**	**$ 45,193**	**$ 46,517**	**$ 47,873**	**$ 49,263**	**$ 51,107**	**$ 52,986**

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Case 3 VM2 And VM3 fail Lose WA (LQ switched via JA) in addition to VM

LQ	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Summer MW		120.4	123.0	125.8	128.5	131.3	134.1	137.5	140.9	144.5	148.1	151.8	155.6
Summer MVA		128.1	130.9	133.8	136.7	139.7	142.7	146.3	149.9	153.7	157.5	161.5	165.5
Summer pf	0.940	0.94	0.94	0.94	0.94	0.94	0.94	0.940	0.940	0.940	0.940	0.940	0.940
WA	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Summer MW		69.3	70.9	72.1	73.4	74.7	76.0	77.9	79.9	81.9	83.9	86.0	88.2
Summer MVA		73.7	75.4	76.7	78.1	79.5	80.9	82.9	85.0	87.1	89.3	91.5	93.8
Summer pf	0.940	0.94	0.94	0.94	0.94	0.94	0.94	0.940	0.940	0.940	0.940	0.940	0.940
Load at risk MVA (WA only)	0.0	73.7	75.4	76.7	78.1	79.5	80.9	82.9	85.0	87.1	89.3	91.5	93.8
High Load factor	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Load factor	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
TF Rating (MVA) 1 tf at WA	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
Correction for VM transfer	15	15	15	15	15	15	15	15	15	15	15	15	15
Load at risk MW	0.0	53.9	55.5	56.7	58.1	59.4	60.7	62.7	64.6	66.6	68.7	70.8	73.0
VCR	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
Probability	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254
Cost	**$ -**	**$ 83,971**	**$ 86,494**	**$ 88,424**	**$ 90,502**	**$ 92,580**	**$ 94,658**	**$ 97,661**	**$ 100,738**	**$ 103,892**	**$ 107,125**	**$ 110,439**	**$ 113,835**

SKM

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
159.4	163.4	167.5	171.7	176.0	180.4	184.9	189.5	194.3	199.1	204.1	209.2	214.4	219.8
169.6	173.9	178.2	182.7	187.2	191.9	196.7	201.6	206.7	211.8	217.1	222.6	228.1	233.8
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
90.4	92.7	95.0	97.3	99.8	102.3	104.8	107.5	110.1	112.9	115.7	118.6	121.6	124.6
96.2	98.6	101.0	103.6	106.1	108.8	111.5	114.3	117.2	120.1	123.1	126.2	129.3	132.6
0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
96.2	98.6	101.0	103.6	106.1	108.8	111.5	114.3	117.2	120.1	123.1	126.2	129.3	132.6
1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938
33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
15	15	15	15	15	15	15	15	15	15	15	15	16	17
75.3	77.6	79.9	82.3	84.8	87.3	89.9	92.5	95.3	98.1	100.9	103.8	107.7	111.7
$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388	$ 61,388
0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254
$ 117,317	**$ 120,885**	**$ 124,543**	**$ 128,292**	**$ 132,135**	**$ 136,074**	**$ 140,112**	**$ 144,250**	**$ 148,492**	**$ 152,840**	**$ 157,297**	**$ 161,865**	**$ 167,922**	**$ 174,096**

Appendix C Probabilistic Assessment for Terminal Station Security Enhancement

Richmond Terminal Station (RTS)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
MD	0	570.7	581.7	593.8	606	618.5	631	643.5	656.1	668.8	685.5	702.7	720.2
Prob of 2 tf failures out of 4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Prob of coincidence	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865
Hours at risk	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
2 TF capability	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5
MVA at risk	0	228.2	239.2	251.3	263.5	276	288.5	301.0	313.6	326.3	343.0	360.2	377.7
Load factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Power Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
MW at risk	0.0	197.3	206.9	217.3	227.9	238.7	249.5	260.3	271.2	282.2	296.6	311.5	326.7
Expected Benefit ($K)	**$ -**	**$ 63.7**	**$ 66.8**	**$ 70.1**	**$ 73.5**	**$ 77.0**	**$ 80.5**	**$ 84.0**	**$ 87.5**	**$ 91.1**	**$ 95.7**	**$ 100.5**	**$ 105.4**

West Melbourne Terminal Station (WMTS)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
MD	0	463.9	499.7	515.1	529.6	544.6	559.8	575.2	591.0	607.0	622.2	637.7	653.7
Prob of 2 tf failures out of 4 tf	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Prob of coincidence	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865
Hours at risk	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
2 TF capability	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5
MVA at risk	0	121.4	157.2	172.6	187.1	202.1	217.3	232.7	248.5	264.5	279.7	295.2	311.2
Load factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Power Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
MW at risk	0.0	105.0	135.9	149.3	161.8	174.8	187.9	201.2	214.9	228.7	241.9	255.3	269.1
Expected Benefit ($K)	**$ -**	**$ 33.9**	**$ 43.9**	**$ 48.2**	**$ 52.2**	**$ 56.4**	**$ 60.6**	**$ 64.9**	**$ 69.4**	**$ 73.8**	**$ 78.1**	**$ 82.4**	**$ 86.8**

Expected Total Benefit	**$ -**	**$ 97.6**	**$ 110.6**	**$ 118.3**	**$ 125.8**	**$ 133.4**	**$ 141.2**	**$ 149.0**	**$ 156.9**	**$ 164.9**	**$ 173.8**	**$ 182.9**	**$ 192.3**
Cost of 1 hour outage to arrange transfers	$ -	$ 0.48	$ 0.55	$ 0.58	$ 0.62	$ 0.66	$ 0.70	$ 0.74	$ 0.77	$ 0.81	$ 0.86	$ 0.90	$ 0.95
Net Benefit ($K)	**$ -**	**$ 97.1**	**$ 110.1**	**$ 117.7**	**$ 125.1**	**$ 132.8**	**$ 140.5**	**$ 148.2**	**$ 156.1**	**$ 164.1**	**$ 172.9**	**$ 182.0**	**$ 191.3**

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
738.2	756.7	775.6	795.0	814.9	835.2	856.1	877.5	899.5	921.9	945.0	968.6	992.8	1017.7
0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865
202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5
395.7	414.2	433.1	452.5	472.4	492.7	513.6	535.0	557.0	579.4	602.5	626.1	650.3	675.2
0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
342.2	358.2	374.5	391.3	408.5	426.1	444.2	462.7	481.7	501.1	521.0	541.5	562.4	583.9
$ 110.4	**$ 115.6**	**$ 120.9**	**$ 126.3**	**$ 131.8**	**$ 137.5**	**$ 143.3**	**$ 149.3**	**$ 155.4**	**$ 161.7**	**$ 168.2**	**$ 174.7**	**$ 181.5**	**$ 188.4**

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
670.0	686.8	703.9	721.5	739.6	758.1	777.0	796.4	816.3	836.8	857.7	879.1	901.1	923.6
0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865	0.0865
202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5	342.5
327.5	344.3	361.4	379.0	397.1	415.6	434.5	453.9	473.8	494.3	515.2	536.6	558.6	581.1
0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
283.2	297.7	312.6	327.8	343.4	359.4	375.8	392.6	409.8	427.4	445.5	464.1	483.1	502.6
$ 91.4	**$ 96.1**	**$ 100.9**	**$ 105.8**	**$ 110.8**	**$ 116.0**	**$ 121.3**	**$ 126.7**	**$ 132.2**	**$ 137.9**	**$ 143.8**	**$ 149.8**	**$ 155.9**	**$ 162.2**

$ 201.9	**$ 211.7**	**$ 221.8**	**$ 232.1**	**$ 242.7**	**$ 253.5**	**$ 264.6**	**$ 276.0**	**$ 287.7**	**$ 299.7**	**$ 311.9**	**$ 324.5**	**$ 337.4**	**$ 350.6**
$ 1.00	$ 1.05	$ 1.10	$ 1.15	$ 1.20	$ 1.25	$ 1.31	$ 1.36	$ 1.42	$ 1.48	$ 1.54	$ 1.60	$ 1.67	$ 1.73
$ 200.9	**$ 210.6**	**$ 220.7**	**$ 230.9**	**$ 241.5**	**$ 252.3**	**$ 263.3**	**$ 274.7**	**$ 286.3**	**$ 298.2**	**$ 310.4**	**$ 322.9**	**$ 335.7**	**$ 348.9**

SKM

Benefits of Transfers between Terminal Stations ($K)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
RTS Transfer Benerfits	$70.1	$73.5	$77.0	$80.5	$84.0	$87.5	$91.1	$ 95.74	$ 100.52	$ 105.42
WMTS Transfer Benefits	$48.2	$52.2	$56.4	$60.6	$64.9	$69.4	$73.8	$ 78.06	$ 82.40	$ 86.85
Expected Total Benefit	$118.3	$125.8	$133.4	$141.2	$149.0	$156.9	$164.9	$ 173.8	$ 182.9	$ 192.3
Cost of 1 hour outage to arrange transfer	$0.6	$0.6	$0.7	$0.7	$0.7	$0.8	$0.8	$ 0.86	$ 0.90	$ 0.95
Net Benefit ($K)	$ 117.7	$ 125.1	$ 132.8	$ 140.5	$ 148.2	$ 156.1	$ 164.1	$ 172.9	$ 182.0	$ 191.3

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
$ 110.45	$ 115.60	$ 120.88	$ 126.29	$ 131.84	$ 137.52	$ 143.35	$ 149.32	$ 155.45	$ 161.72	$ 168.15	$ 174.75	$ 181.51	$ 188.43
$ 91.41	$ 96.08	$ 100.87	$ 105.79	$ 110.82	$ 115.98	$ 121.27	$ 126.69	$ 132.25	$ 137.95	$ 143.78	$ 149.77	$ 155.90	$ 162.19
$ 201.9	$ 211.7	$ 221.8	$ 232.1	$ 242.7	$ 253.5	$ 264.6	$ 276.0	$ 287.7	$ 299.7	$ 311.9	$ 324.5	$ 337.4	$ 350.6
$ 1.00	$ 1.05	$ 1.10	$ 1.15	$ 1.20	$ 1.25	$ 1.31	$ 1.36	$ 1.42	$ 1.48	$ 1.54	$ 1.60	$ 1.67	$ 1.73
$ 200.9	$ 210.6	$ 220.7	$ 230.9	$ 241.5	$ 252.3	$ 263.3	$ 274.7	$ 286.3	$ 298.2	$ 310.4	$ 322.9	$ 335.7	$ 348.9

Appendix D Overall Summary of Benefits for 25 Year Probabilistic Studies

Overall Summary of Benefits arising from Security Enhancement of CBD

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Zone Sub - 1tf	$0	$0	$1,886	$2,656	$2,813	$2,974	$3,136	$3,307	$ 3,478	$ 3,654
VM - Multiple Outages	$0	$0	$248	$339	$352	$364	$377	$390	$ 404	$ 417
Terminal Stations	$118	$125	$133	$140	$148	$156	$164	$173	$ 182	$ 191
Net Benefit ($K)	**$118**	**$125**	**$2,267**	**$3,136**	**$3,312**	**$3,494**	**$3,677**	**$3,870**	**$ 4,064**	**$ 4,263**

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Zone Sub - 1tf	$ 3,836	$ 4,022	$ 4,212	$ 4,407	$ 4,607	$ 4,813	$ 5,024	$ 5,239	$ 5,459	$ 5,686	$ 5,920	$ 6,157	$ 6,404	$ 6,660
VM - Multiple Outages	$ 432	$ 446	$ 461	$ 476	$ 492	$ 508	$ 524	$ 541	$ 558	$ 576	$ 594	$ 613	$ 637	$ 663
Terminal Stations	$ 201	$ 211	$ 221	$ 231	$ 241	$ 252	$ 263	$ 275	$ 286	$ 298	$ 310	$ 323	$ 336	$ 349
Net Benefit ($K)	**$ 4,468**	**$ 4,679**	**$ 4,894**	**$ 5,114**	**$ 5,341**	**$ 5,573**	**$ 5,812**	**$ 6,055**	**$ 6,304**	**$ 6,560**	**$ 6,824**	**$ 7,093**	**$ 7,377**	**$ 7,672**

APPENDIX K. CITIPOWER: REVIEW OF CBD SECURITY OF SUPPLY AND PLANNING STANDARDS TO BE ADDED

SINCLAIR KNIGHT MERZ

SKM

CitiPower
Review of CBD Security of Supply and Planning Standards

UPDATED FINAL REPORT

- 22 August 2006

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Review of CBD Security of Supply and Planning Standards

UPDATED FINAL REPORT

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Contents

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2	5.05.04	K Frearson			Added Reliability section by Ben Kearney
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EXECUTIVE SUMMARY

Sinclair Knight Merz is pleased to submit this report against CitiPower's Terms of Reference titled "Review of CBD Security of Supply and Planning Standards".

The key recommendations of this report are:

a) The planning criteria for the CBD should be changed from the existing (N-1) criterion to the more onerous "N-1 secure" criterion. This recognises the particular significance of the CBD load and the number of people likely to be impacted by a major CBD supply failure.

b) To meet the requirements for improved security of supply, Substations VM and W should be fitted with complete 66kV Gas Insulated Switchgear to enable remote manual switching via the SCADA system, improve operational flexibility and increase transfer capability between Terminal Stations.

c) Brunswick Terminal Station should be developed with 2x225MVA 220/66kV transformers by 2009 to mitigate capacity constraints and reduce the dependence on West Melbourne Terminal Station. As well as providing superior technical benefits, this option provides a present-value cost saving of over $27M (over the first 25 years) compared with the alternative option of a Terminal Station at BSBQ.

d) Sub BQ should be refurbished and developed into a high-capacity Zone Substation with 2 x 66/11kV 60MVA transformers in the first instance.

With regard to the particular requirements detailed in the Scope, SKM provides the following summary:

1. Review of National Electricity Rules Requirements and CitiPower's Own Planning Criteria

The National Electricity Rules (formerly the Code) were reviewed and were found to be essentially silent on the question of security of supply for Distribution Companies. Whilst not directly applicable, several sections of the Rules are relevant in that they provide guidance on the intent and principles of the Rules as they relate to security and reliability of supply to market customers.

CitiPower's CBD present Planning Criteria are a continuation of the standard developed by the SECV and is a function of the design of the supply system into the CBD. The present Planning Criteria have been applied since privatisation of the Electricity Industry and form the basis of CitiPower's CBD Planning Philosophy.

The security standard applicable to Melbourne CBD supply was compared with that of other comparable CBDs in terms of maximum demand, planning criteria and load at risk. SKM ranked the Melbourne CBD's security of supply as the second lowest of the six utilities that provided specific data in response to the questionnaire applied by SKM in its research.

2. Recent Major Events Impacting the Melbourne CBD

SKM reviewed the CBD outage events that occurred in 2001. The key finding of the review was that although CitiPower followed its current Planning Criteria, if the CBD network been designed to higher security standards (eg "N-1 Secure"), the adverse effects of the CBD outages of 2nd January and 9th November 2001 could have been either avoided or reduced in severity. In both events, the prior outages took place a number of days before the loss of supply occurred.

To achieve a higher security standard would require installation of 66kV circuit breakers at Zone Substations and additional 66kV ties between Terminal Stations.

3. Revised Network Planning Criteria

Given the magnitude and importance of the CBD load together with the large number of people affected by CBD interruptions (compared to the number of CBD electricity customers), SKM considers it appropriate to apply the transmission security standards as defined in the National Electricity Rules to the subtransmission network supplying the CBD.

SKM therefore considers the security criteria applied to the CBD network should be increased from the current "N-1" criteria to a more onerous "N-1 secure" criterion. This would enable the network to be returned to a "secure" operating state within 30 minutes of a first contingency, and be capable of withstanding a second contingency event.

SKM believes that using an "N-2" criterion would incur prohibitive costs for little additional benefit.

4. Development of Alternative and Practical Augmentation Options for Future Transmission/Subtransmission Reinforcement to Melbourne CBD

SKM assessed broadly the nature of the works that would be required in order to satisfy the more onerous "N-1 secure" planning criterion. Following on from this work, SKM then developed two conceptually different augmentation options that would meet the requirements of the proposed planning criterion.

- Option 1 (BSBQ) involves developing a 2 x 225MVA 220/66kV Terminal Station at sub BSBQ on the northern fringe of the CBD.
- Option 2 (BTS) involves developing a 2 x 225MVA 220/66kV Terminal Station at the existing Brunswick Terminal Station site (BTS) – some 6 km from the CBD. This Option 2 is the preferred development option.
- Both options have a number of features in common including improved switching at Sub VM and Sub W and some cable works in the CBD. These works are needed to provide the switching and 66kV transfer requirements to meet the proposed "N-1 secure" planning criterion.
- The estimated initial capital cost of the preferred option is **$125.4 M.**
- The initial capital costs exclude overheads and include civil works and refurbishment costs for development of Sub BQ;
- The proposed expenditure is divided into categories as follows:

Terminal Station Costs	**$36.2M**
Zone Substation Costs	**$36.8M**
Security Enhancement Costs	**$52.4M**

- Terminal Station augmentation is required by 2009 to meet forecast capacity constraints.

SCOPE

Terms of Reference for this project are provided in Appendix C and summarised as follows:

1. Review of Regulatory Requirements and CitiPower's Own Planning Criteria

CitiPower requires SKM to review the requirements of the Victorian Electricity Distribution Code, dated January 2002, together with CitiPower's own internal CBD Security of Supply and Planning Review Report dated September 2003.

SKM also suggests that this review should take account of the requirements of the National Electricity Rules (NER) in respect of system security. The NER is generally considered to apply to the security and reliability of transmission systems operated by TNSPs. However, the actual definition of what constitutes a "transmission element" is undefined, and NEMMCO may deem that a particular circuit or system element at subtransmission level may actually be required to comply with NER.

2. Recent Major Events Impacting the Melbourne CBD

CitiPower requires SKM to review reports associated with two major events which recently resulted in loss of supply to the Melbourne CBD. These are the events of 2 January 2001 (SKM report dated March 2001), and 9 November 2001 (PB Associates report dated February 2002).

These reports and the circumstances surrounding the two incidents are to be reviewed in the broader context of whether the security of supply evidenced by the system configuration at the time is deemed adequate for supply to the CBD of a city the size of Melbourne.

3. Revised Network Planning Criteria

Based on the analysis and outcomes of items 1 and 2 above, CitiPower requires SKM to propose revised network planning criteria which reflect an appropriate level of system security for the Melbourne CBD. The revised planning criteria are to reflect international experience together with the best economic and technical outcomes for the electricity consumers within Melbourne.

4. Develop Alternative and Practical Augmentation Options for Future Transmission/Subtransmission Reinforcement to Melbourne CBD

CitiPower requires SKM to develop three economically and technically feasible options for the future reinforcement of the transmission and subtransmission systems to the Melbourne CBD (including the currently favoured option jointly developed by CitiPower/VENCorp).

SKM should provide information that facilitates the economic analysis of options by a 25 year NPV study of capital and operating costs (with operating costs based on average O&M costs per asset class, and cost of losses).

This section of the report reviews the current planning criteria applied to the Melbourne CBD subtransmission network, whether the current criteria are appropriate, and whether SKM considers any changes to the planning criteria is warranted.

This section of the report sets the framework and requirements for the remainder of the report.

Description of Security/Reliability Terms

To appreciate the Regulatory requirements it is appropriate to have a clear understanding of the terms used in discussing security and reliability. The following provides a simple description of the terms:

Term	**Description**
N-1	The network can withstand the loss of any element and maintain supply to all customers
N-1 secure	The network can withstand the loss of any element and maintain supply to all customers. In addition the network can be subsequently re-configured to withstand a further outage without loss of supply. During the time taken to re-configure (which is usually targeted to be 30 minutes), there is a risk of supply interruption if a second contingency occurs.
Modified N-2	The network can withstand the loss of a critical element together with the further loss of a non-critical element. This security standard has been applied to the Sydney CBD.
N-2	The network can withstand the loss of any 2 network elements and maintain supply to all customers. Very few networks have true N-2 security.
Satisfactory Operating State (Section 4.2.2 NER)	Term used in National Electricity Rules to describe a power system that is able to provide electricity in a stable manner and within the prescribed technical envelope (in terms of voltage, frequency, fault levels, ratings, etc). However, when a system operates in this state, load may be interrupted if a network outage occurs.

Secure Operating State (Section 4.2.4 NER)	As for "Satisfactory Operating State" but with the addition of a capability to withstand the occurrence of a single credible contingency and to return to a "Satisfactory Operating State" in accordance with the power system security and reliability standards set out in the NER. Such a system is considered to have a security standard of (N-1).

Regulatory requirements

As a Network Service Provider in the National Electricity Market, CitiPower is subject to a range of requirements under the National Electricity Rules ("the NER") and instruments administered by the Victorian Essential Services Commission. These are summarised below.

National Electricity Rules

The NER is essentially silent on the question of security of supply for Distribution Companies. Whilst not directly applicable, several sections of the NER are relevant in that they provide guidance on the intent and principles of the NER as they relates to security and reliability of supply to market customers. These sections are summarised in the following table, and the relevant sections reproduced in full in Appendix B.

Table 14 National Electricity Rules requirements

Rules ref	Applies to	Summary of requirements
4.2.6.	General principles for maintaining power system security	Ability to return system to a secure operating state within 30 minutes of a credible contingency, including through (underfrequency) load shedding.
S5.1.2.2	Network Service Providers	Degree of network redundancy to take into account the grouping of generating units, capacity factors, availability, and the size and importance of Customer groups. <Appropriate level of supply> to be available during the most critical single element outage, allowing for maintenance to be carried out by the NSP. May also allow for both circuits of a double circuit or two closely parallel circuits to be out of service.

In short, the NER in section 4.2.6 requires "N-1 secure" supply for the interconnected transmission system as a whole. That is, the system should be able to withstand any single worst case contingency, and be capable of being returned to a secure state within 30 minutes of a contingency. In effect this requirement translates into a criterion which SKM would term "N-1 secure". "N-1 secure" is more onerous than "N-1", but less onerous than "N-2".

There is some ambiguity as to the extent that these sections of the NER apply to distribution networks. The more onerous security requirements are generally applied to the interconnected transmission network, rather than distribution networks.

SKM believes that security criteria at the upper end of the range allowed in the NER should apply to the Melbourne CBD. The justification for this lies in the importance of reliable supply to CBD customers and the requirement of S5.1.2.2 that the size and importance of customer groups are taken into account when selecting the appropriate level of supply security. This is discussed in greater detail in Section 4.8 below.

Victorian Jurisdictional Requirements

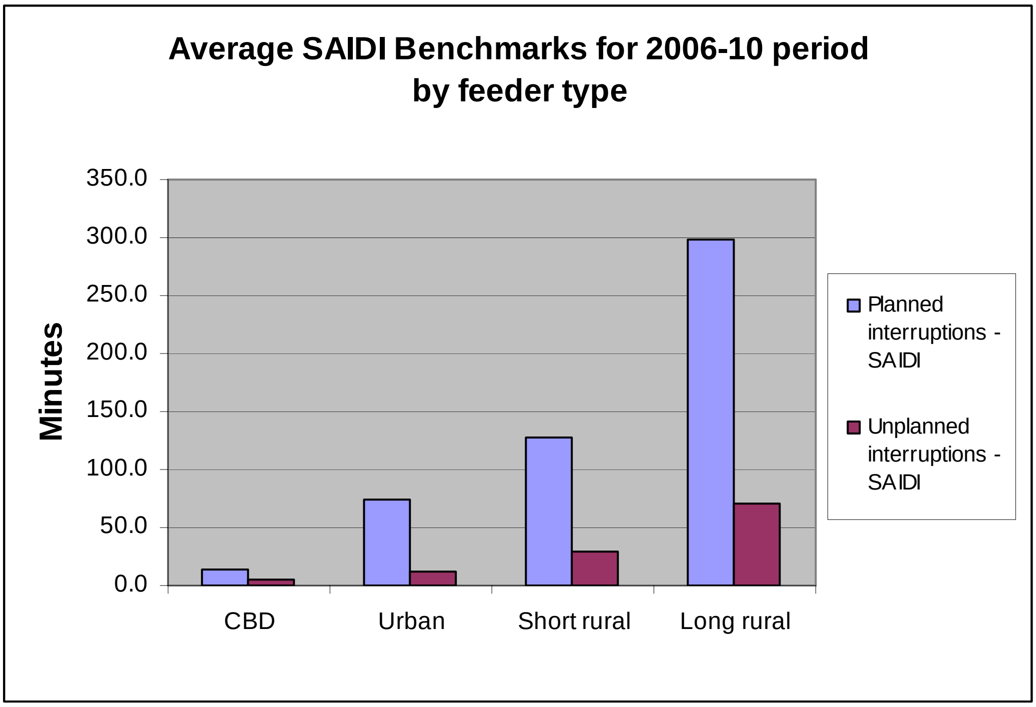
The Office of the Regulator General in Victoria (now the Essential Services Commission) published the Victorian Distribution Code (Jan 2002) and Electricity System Code (Oct 2000). Like the NER, these instruments do not provide specific guidance on the planning criteria to be applied to Distribution Networks, but do contain a number of requirements relating to supply reliability. These requirements include:

- Distributors to annually publish a Distribution Planning Report and a Transmission Connection Planning Report describing their planning criteria, network loading information and proposed major augmentations;
- Distributors to publish reliability targets each year;
- Distributors to use best endeavours to meet the reliability of supply targets contained in the price determination;
- Distributors to use best endeavours to restore supply as soon as possible following a planned or unplanned outage;
- Distributors to make supply restoration payments to each customer affected by interruptions of more than 12 hours, or more than 9 interruptions in a calendar year (15 for rural customers);
- Network Owners to maintain a high degree of reliability and availability (the Electricity System Code contains a number of specific requirements and measures).

The 2006-2010 Distribution Price Determination also contains a service incentive scheme, that defines reliability targets for each distributor and network type, and provides financial incentives (and penalties) for distributors depending on their performance in meeting those targets.

The average[41] targets for each network type are summarised in Figure 1 below. These charts show that the expected reliability for CBD networks is significantly higher than for other network types. The target total interruption time and frequency for CBD customers is around one fifth of urban customers, with zero momentary interruptions. Further details are provided in Appendix J.

The different targets highlight the increased reliability expectations for CBD customers, and the different nature of the CBD network required to continue to meet the specified reliability levels.



[41] Average for all years and distributors as contained in the Electricity Distribution Price Review 2006-10 Final Decision.

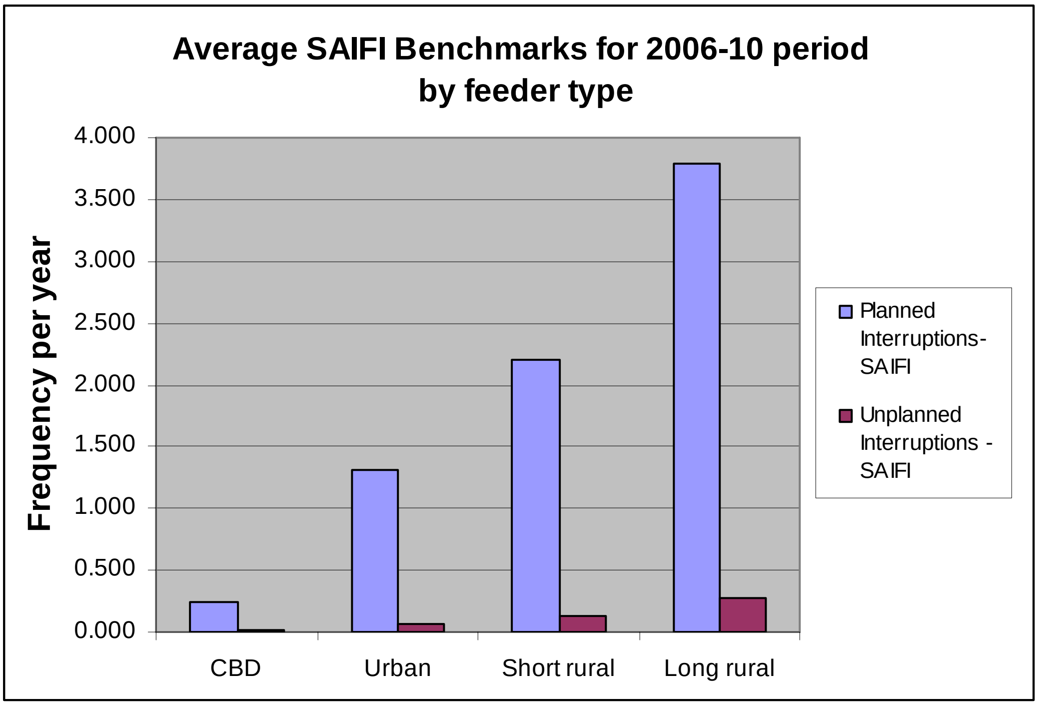


Figure 1 ESC Service standards targets for different network types

Current CitiPower planning criteria

The following extract is taken from CitiPower's 2003 Distribution Planning Report.

In terms of overall planning objectives at the Zone Substation and subtransmission system level, CitiPower aims to achieve a network that is capable of satisfactorily withstanding any single contingency event at the 50th percentile demand forecast without interruption to customers.

This N-1 standard provides for the planned or unplanned removal from service of any line, transformer, circuit breaker, etc at the time of 50th percentile maximum demand loading on the station/system, in a manner such that:

- *there is no requirement to interrupt customer load;*
- *voltage levels on the secondary buses of Zone Substations are maintained within acceptable limits; and*
- *The loading on all remaining in-service elements is within their thermal limits.*

The target planning standards for CBD Zone Substations and the subtransmission lines supplying them are:

- *no customer interruptions following a first order (N-1) contingency;*
- *restoration of supply to a minimum of 50% load following a second order (N-2) contingency;*
- *early restoration of supply to a minimum of 50% load for loss of one Zone Substation;*
- *early restoration of supply up to 50% of load for loss of one sub-transmission level at Terminal Station; and*
- *Provision of supply to minimum of 50% load for loss of all circuits in one easement.*

Note: *An N-2 contingency could involve an initial interruption of all customers, followed by an early restoration of supply to at least 50% of affected customers. Whilst CitiPower's planning standards above imply a strict deterministic approach, the timing of any new augmentation takes into account the probabilistic analysis.*

In summary, CitiPower's current planning criterion for the CBD is to provide an N-1 level of security, with the ability to supply 50% of load in the event of an N-2 contingency within a short period.

This planning criterion is identical to that used by the SECV prior to privatisation.

Reliability of comparable CBDs

SKM recently conducted a study of supply reliability (including criteria) for a number of comparable CBD areas in Australia and overseas. The cities studied were:

- Auckland
- Brisbane
- Cape town
- Glasgow
- Johannesburg
- Melbourne
- Sydney
- Wellington

The study found supply security ranged from virtually full N-2 redundancy, down to N-1. Melbourne was towards the bottom of this group of cities in terms of the security criteria and load at risk.

Ranking Methodology

The comparison of CBD security of supply for the eight (8) cities was carried out using a standardised survey that contained relevant questions in two separate categories. The first category of questions sought information about the planning criteria applied by the utility. The second category of questions sought information about the extent to which the actual network configuration met the planning criteria, or where it did not meet the criteria, the magnitude of load that was at risk for certain specified contingencies. The cities selected for the study were on the basis of them supplying similar magnitudes of load, and having a similar commercial relevance. The magnitude of CBD load supplied varied between 175MVA (Auckland) and 700MVA (Melbourne). However, it should be noted that there are some inconsistencies in the definition of CBD supply. For example, Sydney CBD is quoted as having a maximum demand of only 610MVA which is less than the Melbourne CBD maximum demand.

A comparison of the key responses for the CBD of Melbourne, compared with the other cities in the survey is summarised below.

Survey Question	Melbourne	Other Cities
3. CBD Maximum Demand	700MVA	175-600MVA
10. Is your fundamental security of supply policy deterministic (eg. n-1, n-2, etc), probabilistic (eg. % of time MD is met, or energy at risk approach, etc).	Basically n-1, with probabilistic energy at risk approach used to optimise the timing of system augmentation.	4 utilities indicated n-1 deterministic. 1 utility indicated n-2 for >300MW. 3 utilities indicated probabilistic approach.
11. Please indicate the degree to which your existing system configuration in the CBD meets your planning criteria and indicate the load at risk for non-compliant situations.		
11.1 Maximum single contingency load at risk (one event).	14MVA (2nd worst of respondents)	Nil to 86MVA
11.2 Aggregate load at risk for all single contingency situations (all events).	87MVA (2nd worst of respondents)	Nil to 150MVA

On this basis, SKM ranked Melbourne's security of supply as the second lowest of the six utilities that provided specific data in response to the questionnaire. (Data for Sydney and Wellington was not available for comparison of load at risk).

Characteristics of CitiPower CBD System Configuration

In comparing the security of supply of the CBDs of various international cities, SKM was able to identify some differing underlying philosophies applying to the electrical configuration of the various networks.

For example, it is notable that although the CBD electrical demand in Melbourne was the highest at 700MVA, the highest system voltage used, within the CBD boundary is 66kV. For all the other cities surveyed, the most common system voltage used was either 88kV (South Africa) or 110/132kV (Australia/NZ/Scotland).

In addition, it is notable that the configuration of the 66kV subtransmission network supplying the CBD of Melbourne is a "multiple transformer-ended feeder configuration", compared with a "fully switched" subtransmission system configuration adopted in most other cities. The overall effect of this difference is that a greater amount of capital cost is invested in underground cable and transformer capacity in Melbourne. In contrast, a proportionally higher amount of capital cost is invested in switchgear (circuit breakers) in other cities to ensure that the impact of any single contingency (fault) is limited to the faulted element only.

For example, a subtransmission (33kV-132kV) cable fault in most cities will cause an outage on the cable alone, with no loss of transformer capacity at the Zone Substation. In comparison, a 66kV-cable fault in Melbourne has the potential to result in the loss of up to four zone transformers (most commonly two transformers will be lost). **One of SKM's key recommendations is to eliminate the multiple transformer-ended feeder configurations by adding new switchgear at several critical sites**.

While it is correct to note that some other Australian cities (eg. Sydney and Brisbane) have subtransmission systems that are of the feeder/transformer radial configuration; these are progressively being replaced by fully switched configurations where load growth and economic considerations makes it possible to do so.

SKM's findings show that there has been adequate investment to date in underground cable and transformer capacity in the CBD of Melbourne to cater for the existing CBD demand. However, the problem remains that the system configuration lacks both operational flexibility and load transfer capability to securely manage unplanned contingencies that occur coincidently with planned outages.

Planning Implications of CBD Outages

Background

In 2001, CitiPower had two major events that resulted in loss of supply to the CBD.

The first event was in January 2001 and was the subject of an SKM report "Independent Review following Loss of Supply incidents on 2 January 2001".

The second event was in November 2001 and was subject to a PB Associates report "Investigation into Electricity Supply Outage on 9 November 2001 Affecting Melbourne CBD"

Both of these events are reviewed in more detail in Appendix C. The conclusions of Appendix C are provided in the following section for convenience.

Conclusions (see also Appendix C)

a) Had the CBD network been designed to higher security standards (eg "N-1 Secure"), the CBD outages of 2nd January and 9th November could have been either avoided or reduced in severity. In both events, the prior outages involved took place a number of days before the loss of supply occurred. In other words, the CBD network was left in a "satisfactory operating state" (refer Section 4.1) for a significant period. Had the CitiPower CBD network been returned to a "secure operating state" (refer section 4.1) after each of the planned outages, it would have been in a position to cope with the subsequent forced outages. To achieve this outcome (ie achieve a higher security standard) would have required installation of 66kV circuit breakers at Zone Substations and 66kV ties between Terminal Stations.

b) Using customer numbers alone tends to mask the true impact of loss of supply events in the CBD. The number of people affected in a CBD outage can be over 8 times larger than the number of customers affected.

c) The lack of transfer capacity on the 66kV network had a major impact on both the outage extent and outage duration.

d) The lack of remote switching capacity contributed to the delay in restoration of supply in the 2nd January 2001 incident.

e) In both incidents, an unstated but apparent contributing factor was the limitation imposed by fault level constraints. The fault level constraints prevented better use of the existing network, limited the use of load transfers and prevented the use of spare capacity at adjoining Terminal Stations.

f) Having WMTS supply almost 50% of the CBD load inherently increased the impact of an outage incident at WMTS. Reducing the reliance on any single point of supply will automatically reduce the impact of a major outage.

Value of Customer Reliability

The Value of Customer Reliability (VCR) is a measure of the cost of outages to customers, or the amount they would be willing to pay to avoid such outages. (The Value of Customer Reliability replaces the term Value of Lost Load (VoLL) to avoid confusion with the use of VoLL when referring to market price caps.) The use of VCR combined with estimates of the energy at risk of interruption provides a tool for the economic assessment of investments in reliability enhancement.

In July 2003, VENCorp issued a report on its Electricity Transmission Network Planning Criteria, in which it stated it had increased the value it assigns to VoLL from $10,000 / MWh to $29,600 / MWh.

VENCorp also noted research that identified different values of VCR depending on the type of customer. The sector specific VCR values determined were:

Sector	VCR ($ / MWh) December 2002 Dollars	VCR ($/MWh) June 2006 Dollars
Residential	$11,867	$12,869
Commercial	$56,625	$61,388
Agricultural	$54,782	$60,110
Industrial	$18,531	$20,084
Weighted average	$29,600	

VENCorp also noted its intention to apply sector specific VCRs where investments relate to loads substantially different in character from the state average.

In its Transmission Connection Planning Report, CitiPower uses a similar approach and has derived different VCRs for different Terminal Stations (reflecting the composition - by sector - of load at each station) of as follows:

Terminal Station	VCR ($ / MWh) June 2005 Dollars	VCR ($ / MWh) June 2006 Dollars
Fisherman's Bend TS	$43,400	$44,485
Richmond 22kV TS	$41,250	$42,281
Richmond 66kV TS	$42,662	$43,729
West Melbourne 22kV TS	$44,546	$45,660
West Melbourne 66kV TS	$49,700	$50,943

SKM considers the use of weighted, sector-specific values of customer reliability to be appropriate. However, as noted in further detail below, the adverse effects of a CBD supply interruption extend well beyond the CBD electricity consumers. Thus, SKM believes that the value of customer reliability understates the true cost of CBD supply interruptions.

People Affected by Supply Failure

Customers Affected compared with People Affected

Customer numbers in the CBD are approximately 30,000. When CitiPower or the ESC report on incidents affecting CBD supply, the customer numbers are routinely quoted. However, as shown in Table 2 below, the use of CBD customer numbers dramatically underestimates the number of people that may be affected by a supply failure. SKM estimates that up to 250,000 people could be affected in the event of a complete loss of WMTS (supplying nearly 50% of CBD load). The number of people affected is over 8 times higher than the number of CBD customers.

Table 15 People in CBD on a Daily Basis 2003

Category	CBD daily population
Employed in CBD **	180,000
National and International Visitors ##	90-95,000
Metropolitan and Country Victorian Visitors ##	161,000 – 200,000
Residential ##	20,000
Total Daily Population of CBD	**451,000 – 495,000**

Sources ** Bureau of Statistics

Sustainable City Research Department, City of Melbourne

In general, SKM believes that for most Distribution Businesses it is appropriate to use customer numbers when reporting incidents as they provide a reasonable (and convenient) approximation to the number of people affected. However, in the CBD the population affected is quite different to the customer numbers and this fact should also be taken into consideration.

SKM believes that if proper consideration is taken of the number of people affected by supply failure, then it would be reasonable to apply the NER standards for power system security (as applied to the main transmission system) to the CBD supply.

The key linkage here is the number of people affected. From the data provided in earlier sections, a supply failure to the CBD will affect a large number of people and would be comparable in effect to a major transmission failure elsewhere on the power system.

Loss of supply to the CBD will impact on people in many ways including:

- Traffic chaos due to loss of public transport and lack of signalling;
- Loss of supply to many hospitals (including Royal Children's, Royal Melbourne, Royal Women's, St Vincent's, Mercy and Peter MacCallum Cancer Institute)
- Health and Safety issues with high rise buildings dependent on airconditioning and lifts;
- Loss of economic activity in Banks and Stock Exchange;
- Wharf activity and associated shipping activity will be disrupted;
- Large impact on consumer activities involving shopping, restaurants and hotels.

Recommended Planning Criteria for Melbourne CBD

In light of the above analysis, SKM considers that the use of more onerous security criteria for planning the CBD network is justified. The reasons for this finding are as follows:

- The National Electricity Rules require that the size and type of customer loads be taken into account when planning the electricity network. (Section 5.1.2.2 National Electricity Rules)
- The National Electricity Rules require that the system (transmission network) be planned around "N-1 secure" criteria. (Section 4.2.6 NER)

- The National Electricity Rules require that the planning criteria take into account the need for maintenance on the network. With one element out of service for maintenance, a forced outage on other elements is considered a credible contingency event. (Section 5.1.2.1 NER)
- Given the magnitude and importance of the CBD load together with the number of people (as opposed to "customers") affected by a supply interruption, SKM considers it appropriate to apply the transmission security standards in the NER to the subtransmission network supplying the CBD.
- Analysis of recent outage events in the CBD suggests the CBD outages could have been avoided or substantially mitigated by the adoption of "N-1 secure" planning criteria.

Given these reasons, SKM considers the security criteria applied to the CBD network should be increased from the current "N-1" criterion to a more onerous "N-1 secure" criterion. This would enable the network to be returned to a "secure" state within 30 minutes and be capable of withstanding a second contingency event.

It is worth emphasising that under the "N-1 secure" criteria, there will be a small period where the network is at risk from a subsequent contingency. However, the probability of such an event occurring in the critical interval is remote and the cost of eliminating this risk (eg by going to an "N-2" criterion) is likely to be prohibitive and not consistent with the criteria adopted for other similar CBD's.

FUTURE CBD SUPPLY OPTIONS

The aim of this section is to provide an overview of the issues facing CitiPower in improving the supply to the CBD. The issues described in this section need to be considered when assessing the merits of the augmentation options described in Section 6.

Requirements to Achieve "N-1 secure" criterion

In both of the 2001 outage incidents, the initiating outage took place some days before the loss of supply. This leads to the conclusion that one of the principle issues behind the outage incidents was the lack of capability to re-configure the network. To increase the network security to achieve an "N-1 secure" criterion, to improve operational flexibility and to maximise the use of existing assets requires a number of issues to be addressed, as follows:

- Transfer capability between Terminal Stations needs to be significantly improved in terms of capacity, and both time and effort taken to achieve the transfer.
- Rapid network re-configuration should be achieved by remote control using the SCADA system, rather than local manual switching.
- A fault on the network should only cause the faulted element to be switched out of service. To achieve this outcome will require elimination of the multiple transformer-ended feeders common throughout the CBD network. This issue will require a major investment program to install switching capability at both Sub VM and Sub W.

Factors influencing design options

Quite apart from the question of whether more stringent security standard should be adopted, a number of other factors need to be addressed in developing future options for CBD supply. In particular, CitiPower needs to undertake works to ensure that expected load growth can continue to be met, within the constraints that exist (largely a result of the historical network design). Future development of the network should seek to provide an overall optimal solution, in terms of meeting expected future load growth (through installation of additional capacity) and providing an appropriate standard of supply security. The options for providing enhanced security must therefore be assessed in the context of the network development options available to meet forecast demand growth.

CBD Network Constraints

CitiPower faces the following constraints in developing a long-term plan to supply the CBD: -

- Fault Level control requirements mean that:
  - Transformers are operated in Normally Open Auto-Close (NOAC) mode at Fisherman's Bend Terminal Station (FBTS) and West Melbourne Terminal Station (WMTS) and also at various Zone Substations. Thus there is spare installed capacity which cannot be utilised except under outage conditions and reserve capacity cannot be shared;
  - 66kV Ties between Terminal Stations are limited due to fault level issues. This impacts on the capability of the network to transfer load between Terminal Stations;
- Loading of existing Connection Points indicates a need to provide Connection Point augmentation by 2009;
- Lack of sites for new Zone Substations and Terminal Stations. The consequence of the lack of sites is that maximum use should be made of those sites that are available;
- There are aged components of network (6.6kV pockets and 22kV subtransmission due for replacement);
- Network design using transformer-ended feeders and no circuit breakers. The consequence of this design feature is that a single outage can result in loss of up to 4 transformers at different Zone Substations;
- Space limitations in existing Terminal Stations at WMTS and RTS place constraints on further development;
- Space limitations at existing Zone Substations FR and MP restrict the introduction of circuit breakers and this will restrict the introduction of full switching capability;
- 50% of CBD supply comes from one source (WMTS) which inherently increases the risk of loss of supply;
- All transmission and subtransmission works will have to be underground increasing installation cost and repair cost (although there will be less repairs required);
- The nature of the CBD is changing (eg residential population is increasing in the CBD).

Residential Growth

The growth in CBD residential numbers is expected to be strong over the next decade. This is being led by new residential developments in Southbank and Docklands and refurbishment of older buildings. Table 3 below provides a detailed breakdown of residential populations for each of the designated areas in the City of Melbourne. The areas contained in the defined CBD electricity supply region are underlined.

Table 3 **Inner suburbs population – Actual and Forecast**

Source: Melbourne City Suburbs – Economic and Demographic Profile November 2003

Suburb	1996	2001	2006	2011	2016
Carlton	8798	9766	11717	12719	14242
CBD	2395	8252	12989	17319	21469
East Melbourne	3667	3936	4874	5322	5484
Kensington	3735	4816	5700	6622	6709
North Melbourne	6134	7115	8019	8571	8940
Parkville	5422	5505	6117	8116	8305
SouthYarra/StKilda Rd	5583	5487	6064	6213	6313
West Melbourne	1854	2686	3983	4600	5069
Southbank	2239	4399	8893	13134	16407
Docklands	0	159	5475	11367	16668
City of Melbourne	39827	52121	73831	93983	109606
CBD	**4634**	**12810**	**27357**	**41820**	**54544**
Ratio (CBD/City Melb)	11.6%	24.6%	37.1%	44.5%	49.8%

Figure 2 below also shows the forecast growth in CBD residential population over the period 1996 to 2016. It further demonstrates that most residential growth in the City of Melbourne will occur in the CBD.

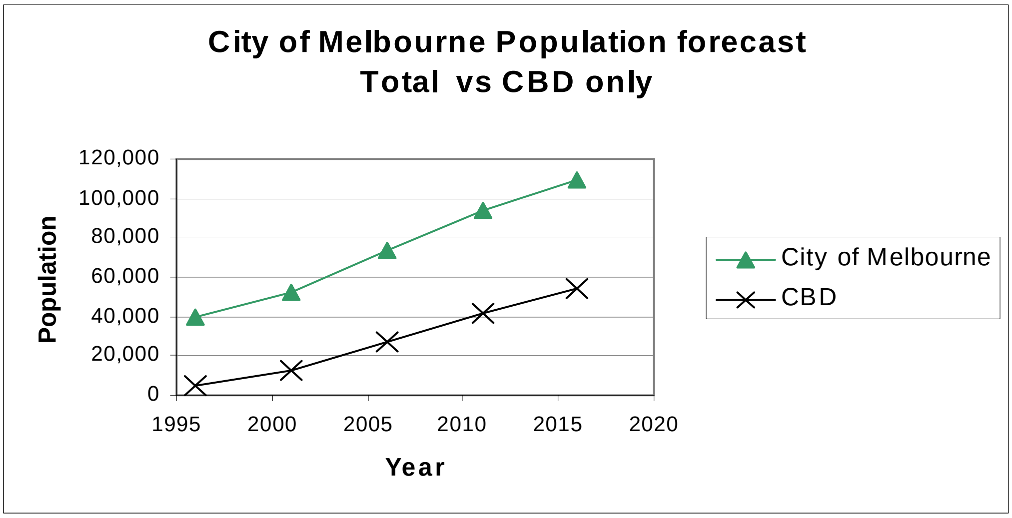


Figure 2 Growth in CBD Residential Population

CBD Load Growth

Figure 3 below shows the forecast growth in CBD loads (Summer MD) from 2004/05 to 2013/14. The data shown represents the CBD load supplied from each of the connection points (Terminal Stations).

This data is based on VENCorp Terminal Station forecasts and assumes that the ratio of CBD load supplied from each connection point remains constant.

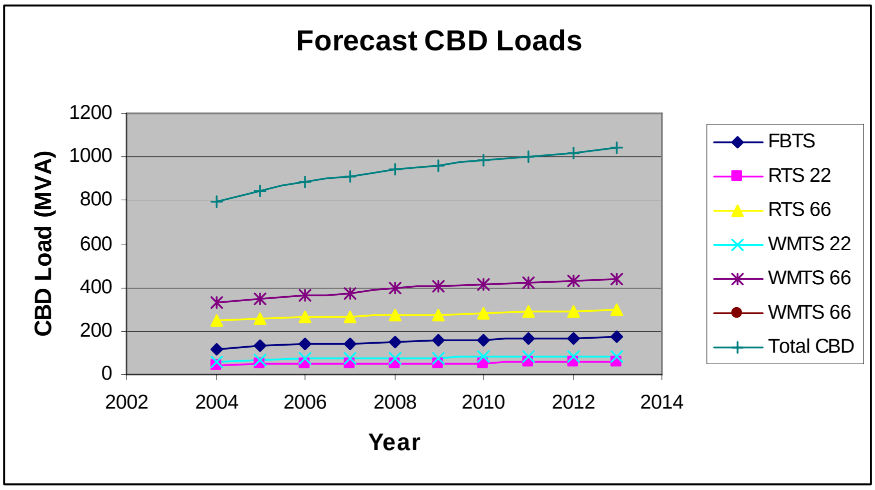


Figure 3 CBD Load Forecast

Figure 4A below shows the cumulative forecast increase in CBD load in each year derived from VENCorp Terminal Station forecasts. Figure 4B below shows the forecast increase in CBD load in each year, derived from CitiPower's Zone Substation Forecast data.

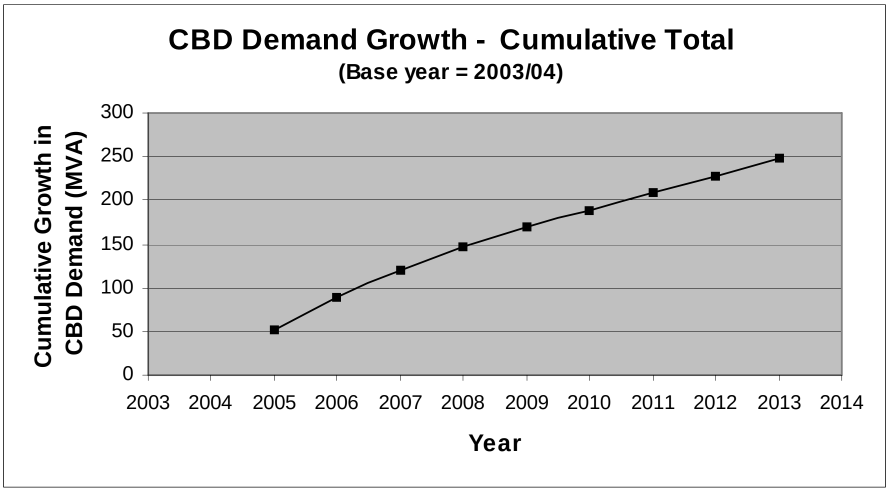


Figure 4 CBD Cumulative Load Increase (from VENCorp Terminal Station Forecast data)

Figure 4 shows that by 2008, there is expected to be an increase of 150MVA in forecast CBD demand over the 2003/04 demand. This is equal to the capacity of the transformer installed in

WMTS in 2001/02. Thus, CBD demand growth alone will require additional transformation capacity at the Terminal Station level by 2009.

Figure 4 also shows that the demand will grow by around 20MVA per year in the longer term. To keep the utilisation factors at their present levels would require the addition of new transformer capacity at least equal to this amount every year over the forecast period. Loading and Capacity of CBD 220/66kV transformers

There are three Terminal Stations that provide supply to the CBD, namely FBTS, RTS and WMTS. Using the forecasts contained in the 2003 Transmission Connection Planning Report the projected loading on the 220/66kV transformers that supply the CBD has been compared with the installedtransformer capacity. The transformer loading is for the summer and includes both CBD and Non-CBD loads. The overall capacity (N) has been determined on the basis of the total nameplate capacity installed at each of the three stations. The (N-1) capacity is 150MVA (ie one transformer) less than the overall capacity. Figure 5 below compares the transformer loading with (N) and (N-1) capacity. The figure indicates that the overall (N-1) capacity will be exceeded around 2008 and assumes there is load transfer capability between Terminal Stations. However, some Terminal Stations will exceed their (N-1) capacity before this date.

Figure 5 CBD 220/66kV Transformers – Load vs Capacity

System Changes impacting on Fault Level

There are two possible changes to the external system that would impact of the CBD fault levels. The possible changes would result in opposite impacts on fault levels as detailed below:

There is significant new generation in the Brooklyn/Altona area. Such generation will increase the fault levels across CitiPower's network. A reduction in fault level margin will exacerbate CitiPower's fault level control difficulties and reduce operational flexibility.

VENCorp has advised that there is a requirement for the continued operation of the FBTS 125MVA Synchronous Compensator and the Brooklyn 110MVA Synchronous Compensator. Furthermore, SPAusNet has recently refurbished the BLTS Synchronous Compensator and expect operation to continue to 2015. Thus the fault level issues at FBTS and WMTS, which are exacerbated by the operation of the Synchronous Compensators, are expected to continue.

Relocation or retirement of the two synchronous compensators would help alleviate fault level issues at both FBTS and WMTS.

Requirements for 66kV Network Improvement

66kV transfer capability

As already noted, SKM believes that the lack of 66kV transfer capability was a key factor in both outage events that occurred in 2001. In addition, limited capacity to transfer loads between Terminal Stations supplying the CBD means that each Terminal Station requires (N-1) capacity, ie there is no capability to share reserve capacity.

To achieve improved transfer capability requires both the installation of additional 66kV cables between selected stations and improved switching capability. Increasing the 66kV transfer capacity would allow loads to be shifted between Terminal Stations in bulk. This would provide the following advantages:

- Optimisation of 220/66kV transformer loading;
- Optimisation of reserve capacity for the 220/66kV transformers (ie remove the need to hold n-1 capacity at each connection point);
- Improved operational flexibility in restoring security levels of the CBD network in response to a planned outage;
- Improved operational flexibility in restoring supply in the event of a widespread CBD outage.

There are technical constraints in establishing permanent ties between the Terminal Stations supplying the CBD. Apart from the fault level constraints, there is the problem of unintended flows arising as a consequence of the 66kV network operating in parallel with the 220kV transmission network. For example, a permanent tie between BTS with RTS via 66kV circuits would be in parallel with the existing BTS-RTS 220kV cable. The RTS-BTS 220kV cable flows will depend on system conditions and could cause unintended flows on a parallel 66kV cable.

The issue of unintended 66kV flows and the need to prevent overloading can be overcome by suitable switching practices (eg establishing parallel connection for a limited time only) or by means of special control features such as automated switching in the event of excessive line flows. The general strategy or procedure could be to operate the network in a radial mode and to only allow parallel ties during a switching sequence.

Fault level control is another reason for minimising the use of permanent ties between Terminal Stations. Again, the general strategy or procedure could be to operate the network in a radial mode and to only allow parallel ties during a switching sequence.

Such operating procedures are in accordance with existing practice on the transmission network.

Improved 66kV Switching

At present there is little remote-controlled switching (by means of circuit breakers) in the CBD Zone Substations. In general, most 66kV switching is achieved by means of isolators that must be de-energised prior to switching. Thus to re-configure the network in the event of an outage, further network elements need to be temporarily taken out of service. Furthermore (see also Section 4.4.2), under forced-outage conditions the lack of fault-interrupting capability results in unnecessary tripping of Zone Substation transformers. For a worst-case 66kV cable outage, up to four transformers at four different Zone Substations may need to be tripped. If one of the affected Zone Substations has a prior transformer outage then the protection trip of a cable would result in overloading of the remaining transformer and loss of CBD loads. The introduction of enhanced switching capability will therefore directly reduce the risk of loss of CBD supply.

In addition, the lack of switching capability restricts rapid transfer capability and slows restoration times.

Improvement in the switching capability to meet the enhanced security requirements and to overcome these switching issues requires:

- Replacement of the existing isolator-based switching facilities with the installation of 66kV Gas Insulated switchgear (GIS);
- The extent of the switchgear replacement program can be minimised by selecting only critical Zone Substations;
- Remote switching of Zone Substations via SCADA can then be developed to improve monitoring, operational response and system flexibility.

The implementation of automated (“smart”) switching on contingency could be investigated as a possibility to help in overcoming fault level constraints and minimising risk of network overloads or supply outages.

Increasing 220/66kV CBD Transformer Capacity

Feasible Options

There are a number of feasible options available for increasing the 220/66kV CBD transformer capacity. These options include development of new sites away from the CBD, new sites on the fringe of the CBD and further development of existing sites. The feasible options are briefly described below.

Inner CBD Options

- Sub BSBQ site. This option is developed in more detail in Section 6.1 and Appendix F.
- Sub B site. The SECV had plans for developing Sub B into an indoor 220/66kV Terminal Station and relocating the 66/11kV Zone Substation to a nearby site. The existing BTS-RTS 220kV cable has been turned in next to the site of Sub B to accommodate this proposal. Unfortunately, the development of this option is restricted by the absence of a suitable Zone Substation site. In concept it is similar to the BSBQ proposal.
- Gas and Fuel site in Smith St Fitzroy. This site has low-level contamination originating from its previous use as a gas storage site. This contamination would not preclude its use as a Terminal Station – it may even make it easier to get community acceptance for development as a Terminal Station. The State government owns the land and is currently seeking to dispose of the site. In concept, development of a Terminal Station on this site would be similar to both the BSBQ option and the sub B option.

Outer CBD Options

- Existing Brunswick 220/22kV Terminal Station. Development of a new 220/66kV connection point at the existing Brunswick 220/22kV Terminal Station. This option is developed in more detail in Section 6.2 and Appendix G
- SP AusNet site located close to Sub Q. This option would be a new 220/66kV development at an existing SP AusNet site. The development would make use of existing 220kV circuits (presently operating at 66kV) running to the site. The site is next to the Eastern Freeway and remote from residential developments.

EXISTING DEVELOPED SITES

- 5th Transformer at WMTS
- 5th Transformer at RTS

These last two options (each involving the installation of a 5th Transformer) may be feasible but are not favoured due to known technical difficulties such as load sharing, adverse impacts on fault levels and space constraints at each site. In addition, increasing the capacity at either of these two sites increases the reliance on a single point of supply.

Further development of these sites could be considered after replacement of some 22kV subtransmission network assets. The space currently being occupied by the 220/22kV transformers and 22kV switchyards could be used to develop new 66kV capacity. Because of the load sharing and fault level constraints, it is likely that the new capacity would be electrically independent from the existing 66kV switchyard. While this idea is worth consideration, at present there is no clear timetable for replacement of the 22kV assets.

Distributed Capacity Option

This option is conceptual only and is based on the use of mini-Terminal Stations at various sites distributed across the CBD, using gas insulated technology (sites not determined). This option is purely speculative and would be extremely expensive (in terms of $/Installed MVA) and would only be considered if none of the sites mentioned above could be developed.

Other Connection Point Strategies

An alternative Connection Point strategy is to develop new or existing Terminal Stations near WMTS and RTS and arrange for these stations to provide supply for the non-CBD components of their load. The objective of this strategy would be to leave WMTS and RTS dedicated to supplying the CBD.

Malvern Terminal Station (MTS) was re-furbished in 2004/05, including installation of larger capacity transformers. In conformance with this strategy CitiPower is planning to construct a 66kV line to MTS to shift load from RTS. This proposal will only reduce the load at risk at RTS and will not impact on WMTS or change the timing requirement for a new Terminal Station.

Non-Network Options for Increasing Capacity

Embedded Generation

In principle, the growth in CBD demand could be supplied by embedded generation. There are currently a number of embedded generators installed in or around the CBD which are run while synchronised to CitiPower's network including hospital generators at Royal Melbourne, St Vincent's and Prince Alfred, Crown Casino at Southbank and the Unichema Factory in Port Melbourne. In addition, there are numerous generators in office blocks and the railways that are capable of providing emergency supply while isolated from the network.

However, to rely on the use of embedded generation to meet demand would require the installation of 20-30MW per year for the forecast period with around 150MW required by 2008. In comparison with the existing embedded generation, these generation requirements could be viewed as a large-scale generation development. Such a development of generation would create adverse environmental impacts in terms of air quality, waste heat and noise. It is likely that with the rapidly increasing residential population there would be the increasing community objection to these environmental impacts. The community opposition to Newport Power Station some 30 years ago highlights the community concern with large-scale generation located in an urban environment.

Furthermore, based on recent examples of gas turbine installations, the EPA may require restrictions on the operating regime of such embedded generators as part of their generating licence.

Other difficulties with the use of embedded generation include:

- Lack of suitable sites;
- Adverse impact on Fault Level;
- The need to spread embedded generation across a number of sites in the CBD to meet load growth.

It could prove feasible to utilise the emergency generators available in most office blocks. The concept would be that building management would turn on their emergency generation (after disconnecting from the network) at times of high demand. In return, the DSM participants would receive a payment from CitiPower. However, SKM does not believe this option represents a viable long-term approach given that most of the emergency generators are diesel-fuelled (with the attendant air-quality issues) and generally do not have the capacity to meet their building's maximum summer demand.

Demand Side Management

Curtailing load at times of maximum demand can be used to control growth in demand. This technique is referred to as Demand Side Management (DSM) and is particularly attractive when the load has a very sharp peak lasting for only a few percent of the time. In Victoria, loads of 90% or more of the maximum demand only occur for approximately 1% of the time.

A DSM response could be used to protect against multiple 220/66kV transformer failures at Terminal Stations and to provide security enhancement for multiple outages of 66/11kV transformers at the CBD Zone Substations.

DSM Response for 220/66kV Outages

The amount of load required to provide a viable DSM response in the CBD can be estimated as the difference between an (N-2) and an (N-1) capacity at each Terminal Station. For example, we can assume that the network is designed to (N-1), ie all load is supplied for loss of a single element. To keep the 220/66kV transformers at a Terminal Station within rating, all loads would be supplied for loss of a transformer but load would have to be shed in the event of a further transformer outage.

Under such arrangements, to protect against equipment damage due to overloading, wide-spread load shedding would be required. This is essentially what occurred in the incident on 9th December 2001.

To prevent the need for widespread load shedding for loss of two transformers, there would need to be a DSM response of at least equal to the capacity of one transformer ie 150MVA.

As there is little transfer capacity between the Terminal Stations supplying the CBD, both RTS and WMTS would require a DSM response of this magnitude ie 150MVA of DSM response at each site.

DSM Response for Security Enhancement

Using a similar approach, the DSM response required to provide security enhancement for each CBD Zone Substation can be estimated as follows:

Demand Side Management - Security Enhancement					
CBD Zone Substation	Transformer Rated Capacity MVA			2006/07 Summer MD	**DSM** Required by each Zone Substation (MVA)
	(Installed)	(N-1)	(N-2)	MVA	
FR	90	60	30	60.6	30
JA	165	110	55	98.5	55
LQ (NOAC on Tx2)	120	120	60	121.2	60
MP	165	110	55	140.1	55
VM	84	54	27	64.7	27
WA	84	54	27	65.3	27
					254 MVA

This table shows the DSM requirement at each of the major CBD zone substations to achieve a security standard equivalent to "N-1 secure". It can be seen from the table that adding the DSM response to the (N-2) capacity at each station restores each station to its (N-1) capacity.

DSM Response for both Terminal Station and Security Enhancement

The table below shows the break-up the Zone Substation DSM requirements by Terminal Station source.

CBD Zone Substation	DSM by Terminal Station (MVA)	
	WMTS	RTS
FR		30
JA	55	
LQ (NOAC on Tx2)	60	
MP		55
VM	27	
WA	27	
	169	**85**

.

From this table it can be seen that the DSM response from the substations supplied by WMTS is greater than the required DSM response of 150MVA for Terminal Stations. On the other hand, the DSM response from the substations supplied by RTS (FR and MP) is less than the required DSM response for Terminal Stations. Thus an additional 65MVA of DSM response would need to be found from other non-CBD substations supplied from RTS, giving a total DSM requirement of 319MVA..

Combining Embedded Generation and DSM

The table in the previous section shows the DSM response required for each CBD Zone Substation and the Terminal Stations supplying the CBD. The same magnitudes and locations would apply if the CBD supply was to be supported by embedded generation.

The use of DSM or embedded generation is interchangeable in the context of supporting the CBD.

Summary of Non-Network Options for Network Support

In summary, the total response (Embedded Generation and/or DSM) required to support both the existing Terminal Stations and to achieve a security standard equivalent to the proposed security enhancement works is as follows:

CBD Substation	Non-Network Support by Terminal Station (MVA)	
	WMTS	RTS
FR		30
JA	55	
LQ (NOAC on Tx2)	60	
MP		55
VM	27	
WA	27	
Other (Non - CBD)		**65**
	169	**150**
	TOTAL SUPPORT	**319MVA**

The two key issues for DSM are the availability of interruptable loads and their location.

The benefits of a DSM response will be reduced if the DSM requirements for each location are only partially satisfied.

Other issues with DSM include:

- There could be health and safety issues (and possible legal liability issues) associated with voluntary load curtailment if it involved reduction in air-conditioning during summer within buildings with no natural air flows. Load curtailment resulting in reduced air-conditioning is quite likely given that maximum demand occurs in summer and that this load has a significant air-conditioning component.

The Zone Substation DSM requirements represent approximately 50% of the Zone Substation Summer MD. As such, the amount of load shedding under a double-contingency condition (N-2) using a DSM response would be similar to the existing CitiPower procedures for emergency load shedding to remove overloads. Hence, the DSM benefits to customer security of supply could be questioned.

OPTIONS FOR AUGMENTATION

Two network options - which would meet the requirements of improving security of supply to the CBD and meet the capacity requirements into the future - have been developed. Both options have a number features in common including improved switching at Sub VM and Sub W and some cable works in the CBD to address the switching and 66kV transfer requirements discussed in previous sections. In addition, both options provide increased 220/66kV-transformer capacity and reduction in CBD load supplied from WMTS.

Option 1 (BSBQ) involves initially developing a 2 x 225MVA 220/66kV Terminal Station (ultimate 3 transformer capacity) at sub BSBQ on the fringe of the CBD and creating 66kV transfer capacity with West Melbourne Terminal Station. For further details see Appendix H.1.

Option 2 (BTS) involves initially developing a 2 x 225MVA 220/66kV Terminal Station (ultimate 4 transformer capacity) at the existing BTS site – some 6 km from the CBD. An important feature of this option is the development of additional 66kV transfer capability between both West Melbourne and Richmond Terminal Stations by means of modification to existing 66kV loops. For further details see Appendix H.2.

The two options are conceptually different –

- The BSBQ option requires 220kV supply to be brought into the CBD area by means of 220kV cables;
- The BTS option makes use of existing 220kV circuit capacity and uses 66kV cables to bring supply into the CBD.

Option 1 BSBQ 220/66kV Terminal Station

The key feature of this option is that it makes use of the existing BSBQ site to provide an injection point at the very edge of the CBD district. This means that it is relatively straightforward to incorporate its supply into the existing 66kV CBD network. The BSBQ site is indoors and was originally designed for 220kV cable supply.

Given the possibility of network constraints on the 220kV supply to WMTS, the most likely source of 220kV supply would be via new 220kV cables from BTS and RTS. The cost of these cables has been factored into the cost analysis for this option. In this analysis, it has been assumed that the 2nd BTS-RTS 220kV cable would be developed at some time in the future as part of the shared transmission network and that CitiPower would be liable for a 20 year “bring-forward” cost.

The major weakness of this option is that capacity would be limited to 3 x 225MVA 220/66kV transformers for an ultimate firm (N-1) capacity of 450 MVA. Consequently, additional 220/66kV augmentation at a new site would be required in approximately 18 years from commissioning.

The **initial** capital costs associated with the BSBQ Option (in $2006) are estimated to be **$147.2M** (undiscounted) as shown below:

Demand –Related Reinforcement	$31.6M
Security Enhancement	$39.5M
Transmission and Connection Asset Costs	$76.0M
Total	$147.2M

The **25-year development** costs (undiscounted) based on this option are estimated to be **$275.6M.** The NPV of these costs over 25 years (at 6.4% Discount Rate and assuming a 40 year asset life) is estimated to be **$134.8M.**

This cost includes Terminal Station development (beyond the initial BSBQ site), Zone substation development assuming approximately 25 MW growth per year for the 25 year period and Security Enhancement works.

Option 2 BTS 220/66kV Terminal Station

The main feature of this option is the development of a 220/66kV facility at an existing Terminal Station site. The site is capable of development to an ultimate installed capacity of 4 x 225MVA (900MVA) or 675MVA firm. Major advantages of this option are the size of the ultimate installed capacity and the presence of existing 220kV circuits of sufficient capacity.

An additional advantage of the BTS option is the capability to shift existing 66kV loops from both WMTS and RTS. In comparison with the BSBQ option this feature would provide both increased tie capacity and the flexibility to shift additional load between Terminal Stations.

The major disadvantage of this option is the need to bring 66kV cables over 6 km into the CBD.

The **initial** capital costs associated with the BTS option (in $2006) are estimated to be **$125.4M** (undiscounted), as shown below.

Demand –Related Reinforcement	$36.8M
Security Enhancement	$52.4M

Transmission and Connection Asset Costs	$36.2M
Total	$125.4M

The **25-year development** costs (undiscounted) based on this option are estimated to be **$245.3M.** The NPV of these costs over 25 years (at 6.4% Discount Rate and assuming a 40 year asset life) is estimated to be **$107.5M.**

This cost includes Terminal Station development (beyond the initial BTS site), Zone substation development assuming approximately 25 MW growth per year for the 25 year period and Security Enhancement works.

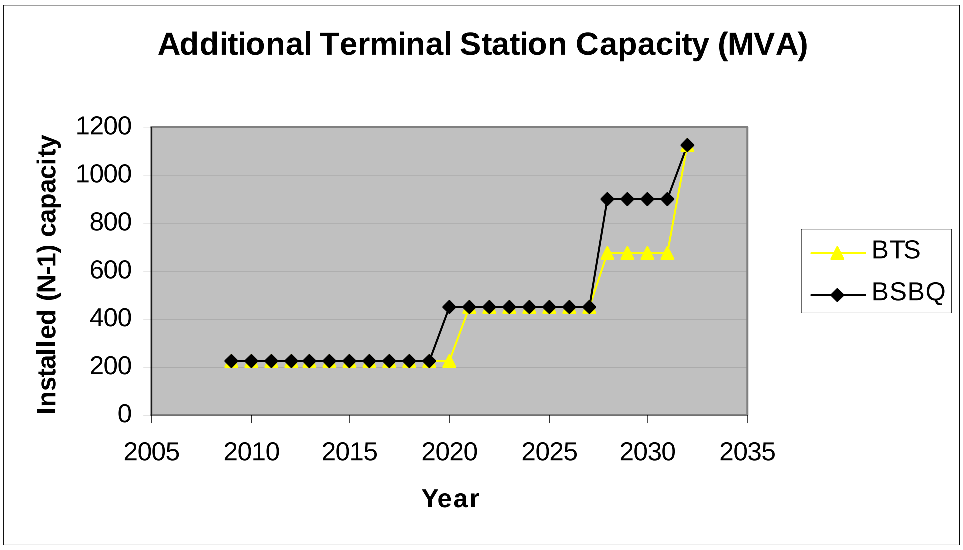
DEVELOPMENT SCENARIOS

25-year development scenarios for both BTS and BSBQ options are provided below. The scenarios are indicative only but they show when expenditure is likely to be required given the assumed demand growth and maintaining asset utilisation at around existing levels.

The expenditure for each item has been spread over time to approximate practical project expenditure. The spread ratios reflect the nature and extent of each item. The expenditures listed below are factored into the NPV assessment in Appendix I.

The major assumptions are:

- CBD demand growth assumed at 20-25MW per year to the end of the 25-year period;
- The firm (N-1) capacities provided by both options are comparable and match the forecast growth in demand;
- At the end of the 25-year period, the two scenarios provide functionally equivalent capabilities (see chart below).
- Zone Substations after the initial works will be high-capacity substations and consequently, their costs will be common to both options.



25-Year Development Scenarios

The tables below shows the estimated capital expenditure, expressed in real $ M at 2006 prices, for each option.

a) Option 1 BSBQ   25-Year development scenario (Terminal Station and Zone Substations)

BSBQ Option

Year		Connection Assets	Demand Related	Total (Connection + Demand) $M	Security Enhance $M
2007	BSBQ 2 x 225MVA 220/66kV and	$7.60	$3.16	**$10.77**	
2008	BSBQ 3 x 30MVA 66/11kV	$22.81	$25.31	**$48.13**	
2009	As above	$38.02	$3.16	**$41.19**	**$14.01**
2010	As above	$7.60		**$7.60**	**$13.78**
2011				**$0.00**	**$11.71**
2012					
2013	Sub W 2x60MVA 66/11kV	$9.36		**$9.36**	
2014					
2015					
2016					
2017					
2018					
2019	Sub W 1x60MVA 66/11kV	$4.42		**$4.42**	
2020	BSBQ TS 3rd 225MVA transformer	$10.00		**$10.00**	
2021					
2022	Zone Substation XXX 2 x 66/11kV 60MVA transformers	$9.36		**$9.36**	
2023					
2024					
2025					
2026					
2027	Zone Substation XXX 3rd 60MVA 66/11kV transformer	$2.63		**$2.63**	
2028	BTS 2 x 225MVA 220/66kV transformers + 4 x 66kV cables to New Zone Sub	$73.36		**$73.36**	
2029					
2030	2nd New Zone Substation 2 x 66/11kV 60MVA transformers	$9.26		**$9.26**	
2031					
2032	BTS 1 x 225MVA 220/66kV transformers + 4 x 66kV cables to New Zone Sub	$10.00		**$10.00**	

Note: Terminal Station Expenditure

b) BTS 25-Year Development Scenario (Terminal Station and Zone Substation)

BTS Option

Year	Item	Connection Assets ($M)	Demand Related	Total (Connection + Demand) $M	Security Enhance ($M)
2007	BTS TS 2 x 225MVA 220/66kV &	$ 3.43	$3.68	**$ 7.11**	
2008	BSBQ ZS 2 x 60MVA 66/11kV	$ 10.28	$29.45	**$ 39.73**	
2009	as above	$ 18.08	$3.68	**$ 21.76**	**$14.20**
2010	as above	$ 3.43		**$ 3.43**	**$15.99**
2011				**$ -**	**$22.22**
2012					
2013	BSBQ 3rd 60MVA 66/11k/V Transformer		$ 4.42	**$ 4.42**	
2014					
2015					
2016					
2017					
2018					
2019	Sub W 2 x 66/11kV 60MVA transformers		$ 9.36	**$ 9.36**	
2020	BTS 3rd 225MVA transformer	$ 10.00		**$ 10.00**	
2021					
2022					
2023					
2024					
2025	Sub W 3rd 60MVA 66/11kV transformer		$ 4.42	**$ 4.42**	
2026					
2027					
2028	BTS 4th 225MVA transformer	$ 10.00		**$ 10.00**	
2029	New Zone Substation 2 x 66/11kV 60MVA transformers		$ 9.36	**$ 9.36**	
2030					
2031					
2032	New Terminal Station 2 x 225MVA transformers + 4 x 66kV cables	$ 73.36		**$ 73.36**	

Note: Terminal Station Expenditure

Timing of "Common Works"

There are a number of works common to both the BSBQ and BTS options. The prime function of these works is to improve security of supply to the CBD therefore they should be considered as "security enhancement" projects. The table below summarises these works, showing location, cost and timing.

More details of the Common Works are provided in Appendix G.3.

Costs Common to Both Options - Security Enhancement

Site	Works	Unit Cost ($2006)	Qty	Total Cost ($2006)	Year
Sub VM	Replace 9x66kV isolators with 16 GIS CB's and isolators	$ 736,299	16	$ 11,780,780	2010
	Station Refurbishment	$ 1,051,855	1	$ 1,051,855	2010
Sub W	Replace 7 x 66kV isolators with 7GIS CB's + isolators with room for expansion to further 4 x 66kV CB's making use of GIS	$ 736,299	7	$ 5,154,091	2009
	Install 2x 66kV 120MVA cable from Sub W to BSBQ	$3,786,679	1.95	$7,384,025	2009
	Station Refurbishment	$ 1,051,855	1	$ 1,051,855	2009
Sub FR	Install additional 1x 66kV Link	$ 368,149	1	$ 368,149	2010
Sub MP	Install additional 1x 66kV Switch Link	$ 368,149	1	$ 368,149	2010
			Total	**$ 27,158,905**	

COST OF OPTIONS

Preliminary Cost Estimates

Preliminary budget costs for the initial development phase for each of the options have been prepared. The costs include Terminal Station costs, Zone Substation costs and Security Enhancement-related costs.

The costs for the different elements have been prepared in conjunction with CitiPower. CitiPower's knowledge of the constraints at each site and the costs of plant items have been incorporated into the development and expenditure scenarios listed in Appendix H. SPI PowerNet has provided assistance in estimating the costs of 220kV cables into the CBD.

The costs are estimates only and may vary when subject to detailed analysis. In particular there are two areas where the estimate of costs will be prone to inaccuracy. The two areas are:

- <u>Cable routes into the CBD</u>. The cable routes are likely to be subject to space constraints and congestion. The assumed route lengths could be quite different once these issues are taken into account and the routes are fully determined and surveyed.
- <u>Building refurbishment costs.</u> Refurbishment costs are difficult to estimate accurately without a detailed building survey being undertaken, which is beyond the scope of this report. However, SKM has provided a brief report on refurbishment costs in Appendix K that aims to capture some of the major costs of refurbishment. These costs have been incorporated into the cost analysis.

The network augmentation costs have also been aggregated into categories to enable a clearer understanding of where the proposed expenditure will lie, and to assist in preparing budgets.

Scenarios for Long-Term Cost Analysis

When evaluating the costs for each option, it is necessary to consider the long-term development scenario costs for each option as well as the initial costs. The development and expenditure scenario for each option has been taken out for 25 years to 2032. The network development scenarios have assumed approximately equal installation of firm capacity at both the Terminal Station and Zone Substation levels, for both options. The zone substation development has assumed that transformer utilisation will remain approximately the same as at present.

The timing of the augmentations for each option has been based around an incremental load growth of 20-30MW per year. Changes to the forecast load growth will impact on the timing of the developments. In addition, when the time for augmentation approaches it can be expected that CitiPower will ensure that the timing of any capital expenditure is optimised, taking into account a detailed consideration of factors such as the value of expected unserved energy, the use of load transfers and power factor correction.

Full details of the 25-year development and expenditure scenario for each option are provided in Appendix H. A more detailed cost evaluation for each scenario is provided in Appendix I. The table below summarises the key results.

Table 6 Summary of costs for each development option

	Option 1: BSBQ TS **2 x220/66kV transformers**	**Option 2: BTS 2x220/66kV transformers**
Initial Works		
Capital Cost of Initial Works (undiscounted)	**$147.2M**	**$125.4M**
Initial Expenditure on **Terminal Stations**	$76.0M	$36.2M
Initial Expenditure on **Zone Substations**	$31.6M	$36.8M
Initial Expenditure on **Security Enhancement**	$12.3M	$25.2M
Expenditure on Common Works **Security Enhancement**	$27.2M	$27.2M
25-Year Development		
Capital Cost (undiscounted) of 25 year development scenario (Terminal Stations, Zone Substations, 66kV cable works and Common Works)	**$275.6M**	**$245.3M**
NPV (at 6.4%) of 25-year	**$134.8M**	**$107.5M**

development scenarios		

Discussion

The total undiscounted cost of the initial works for Option 1 (BSBQ) is approximately $22M more than for Option 2 (BTS), although the undiscounted cost of the Security Enhancement works - one component of the total costs - under Option 1 is expected to be $13 M lower under Option 1. This is due to the high cost of the 220kV cable and the cost of building refurbishment under Option 1. On the basis of undiscounted total costs, there is therefore a clear preference for Option 2 (BTS). In addition, the 25-year development scenarios show that as a result of the capacity limitations of Option 1 (development to only 3 transformers) there will be a need for a new Terminal Station 18 years after the initial development compared with 25 years for the BTS option. The cost of such a station increases the cost of Option 1 relative to Option 2. In present-value terms (at a discount rate of 6.4% real) the total cost of Option 1 (BSBQ) estimated over the first 25 years is approximately $27M higher than that of Option 2 (BTS). This confirms that Option 2 is clearly preferred on the basis of total present-valued cost.

While the cost differential is very significant, there are also technical reasons for preferring Option 2 (BTS), including:

- The BTS Option has more capability to shift load on a permanent basis between adjacent Terminal Stations by means of the existing 66kV loops from WMTS and RTS to BTS.
- The BTS Option allows the development of Sub BQ into a high capacity 66/11kV Zone Substation.

In SKM's opinion, the BTS Option provides significantly more "value for money" than Option 1.

SUMMARY OF OPTIONS

The following table summarises the costs and capabilities of each of the options for CBD augmentation.

Criteria	**Option 1: BSBQ TS 3x220/66kV transformers**	**Option 2: BTS 2x220/66kV transformers**
Cost of Initial Works	**$147.2M**	**$125.4M**
Initial Expenditure on **Terminal Stations**	$76.0M	$36.2M
Initial Expenditure on **Zone Substations**	$31.6M	$36.8M
Initial Expenditure on **Security Enhancement**	$12.3M	$25.2M
Expenditure on Common Works **Security Enhancement**	$27.2M	$27.2M
Cost of 25-Year Development	**$275.6M**	**$245.3M**
NPV of 25-Year Development (at 6.4% for 25 year development scenario, including TS, ZS, 66kV cables and Common Works)	**$134.8M**	**$107.5M**
Terminal Station Installed Capacity (initial)	450MVA	450MVA
Terminal Station FIRM Capacity (initial)	225MVA	225MVA

66kV Switching Capability	✓	✓
66kV Load Transfer Capability	✓	✓✓
66kV Tie Capability between Terminal Stations	✓	✓✓
Reduces WMTS loading	✓	✓✓
Reduces RTS loading	**X**	✓✓
Meets “N-1 secure” criterion	✓	✓

RECOMMENDATIONS

On the basis of the findings contained in this report, the following recommendations are made:

a) The planning criteria for the CBD should be changed from the existing (N-1) criterion to the more stringent "N-1 secure" criterion. This recognises the particular significance of the CBD load, the high and widespread costs of CBD supply interruption and the number of people likely to be impacted by a major CBD supply failure.

b) To meet the requirements for improved security of supply, Substations VM and W should be fitted with complete 66kV Gas Insulated Switchgear in a "double bus" arrangement with remote manual switching capability via the SCADA system.

c) To improve security of supply, the multiple transformer-ended feeders should be modified so that only one transformer is taken out of service in the event of a cable failure.

d) For security enhancement purposes, additional 66kV circuits should be developed between substations in the CBD as shown in Appendix F.

e) CitiPower should develop additional Terminal Station capacity by 2009.

f) The development of Brunswick Terminal Station to a 220/66kV station provides the best long-term solution for the CBD supply in terms of cost, achievability, ultimate capacity, load reduction at WMTS and RTS, and the capability to transfer load between adjacent Terminal Stations. Full development of BTS to 4x225MVA transformers should be sufficient to meet CBD demand for the next 25 years in accordance with the "N-1 Secure" criterion.

   - BTS should be developed with 2x225MVA 220/66kV transformers in the first instance. Over a 25-year period and applying a 6.4% real discount rate, this option provides an NPV cost saving of approximately $27M over Option 1 (BSBQ).
   - Both the WB-C-NC 66kV loop (ex-WMTS) and the CW-B-NR 66kV loop (ex-RTS) should be connected to BTS. Such connection should be carried out in such a manner as to keep the ability to shift each loop back to its original source by means of simple remote switching via SCADA.

g) Sub BQ should be refurbished and developed as a high-capacity Zone Substation with 2 x 66/11kV 60MVA transformers in the first instance.

h) CitiPower should commence investigations into establishing a Terminal Station site to follow Brunswick. SPI AusNet has advised the availability of a site in Kew (KWTS) near the Eastern Freeway. Another site to investigate is the Gas and Fuel site in Smith Street, Collingwood.

Appendix E Terms of Reference

Background

CitiPower's current sub-transmission planning criteria are deterministic in nature overlayed with a probabilistic analysis to determine the timing of an individual augmentation project. This is consistent with CitiPower's obligations under clause 3 of the Victorian *Electricity Distribution Code*.

In 2001, a complete Zone Substation within the central business district CBD was tripped off, and the event lead to additional load shedding at some buses of adjacent Zone Substations. SKM reviewed these events in a report commissioned by CitiPower immediately following this significant outage. In November 2001, the SPI PowerNet owned West Melbourne Terminal Station was tripped off supply, causing a loss of supply to approximately half of Melbourne's CBD customers.

Both events attracted the interest of the Essential Services Commission.

Aim

CitiPower is seeking to engage its customers, and the Essential Services Commission, in a debate over the costs and benefits of an increase in the 'level' of supply security to the Melbourne CBD.

Deliverables

The deliverables of the consultancy are to include:

a) A description of alternative practical methods to effectively increase the level of supply security considering the transmission connection and sub-transmission networks supplying the Melbourne CBD.

b) Recommend the most appropriate method from the above that is consistent with worldwide best practice for CBD networks of a similar size to Melbourne.

c) Propose a revised network planning criteria for CitiPower to adopt, incorporating the recommended approach to increasing the level of supply security.

Issues to consider

The analysis should consider the following relevant documents:

a) "A Comparison of the Security of Electricity Supply to CBD's" SKM Dec 2003.

b) "CBD Security of Supply and Planning Review", CitiPower, September 2003.

c) "Independent Review following Loss of Supply Incidents on 2 January 2001" SKM, March 2001.

d) "Investigation into Electricity Supply Outage on 9 November 2001 Affecting Melbourne CBD", PB Associates February 2002

e) "Victorian Electricity Distribution Code", ESC, January 2002

f) "Distribution System Planning Report", CitiPower, December 2003

Appendix F Relevant sections of the National Electricity Rules

4.2.6 General principles for maintaining power system security

The *power system security* principles are as follows:

(a) To the extent practicable, the *power system* should be operated such that it is and will remain in a *secure operating state*.

(b) Following a *contingency event* (whether or not a *credible contingency event*) or a significant change in *power system* conditions, *NEMMCO* should take all reasonable actions:

(1) to adjust, wherever possible, the operating conditions with a view to returning the *power system* to a *secure operating state* as soon as it is practical to do so, and, in any event, within thirty minutes; or

(2) if any principles and guidelines have been *published* under clause 8.8.1(a)(2a), to adjust, wherever possible, the operating conditions, in accordance with such principles and guidelines, with a view to returning the *power system* to a *secure operating state* within at most thirty minutes.

(c) Adequate *load shedding* facilities initiated automatically by *frequency* conditions outside the *normal operating frequency excursion band* should be available and in service to restore the *power system* to a *satisfactory operating state* following significant multiple *contingency events*.

(d) **[Deleted]**

(e) Sufficient *system restart ancillary services* should be available in accordance with the *system restart standard* to allow the restoration of *power system security* and any necessary restarting of *generating units* following a *major supply disruption*.

S5.1.2.2 Network service within a region

The following paragraphs of this section set out minimum standards for certain *network services* to be provided to *Registered Participants* by *Network Service Providers* within a *region*. The amount of *network* redundancy provided must be determined by the process set out in clause 5.6.2 of the *Rules* and is expected to reflect the grouping of *generating units*, their expected capacity factors and availability and the size and importance of *Customer* groups.

The standard of service to be provided at each *connection point* must be included in the relevant *connection agreement*, and must include a *power transfer capability* such as that which follows:

(a) In the *satisfactory operating state*, the *power system* must be capable of providing the highest reasonably expected requirement for *power transfer* (with appropriate recognition of diversity between individual peak requirements and the necessity to withstand *credible contingency events*) at any time.

(b) During the most critical single element *outage* the *power transfer* available through the *power system* may be:

  (1) zero (single element *supply*);

  (2) the defined capacity of a backup *supply*, which, in some cases, may be provided by another *Network Service Provider*;

  (3) a nominated proportion of the normal *power transfer capability* (eg 70 percent); or

  (4) the normal *power transfer capability* of the *power system* (when required by a *Registered Participant*).

In the case of clauses S5.1.2.2(b)(2) and (3) the available capacity would be exceeded sufficiently infrequently to allow maintenance to be carried out on each *network* element by the *Network Service Provider*. A *connection agreement* may state the expected proportion of time that the normal capability will not be available, and the capability at those times, taking account of specific design, locational and seasonal influences which may affect performance, and the random nature of element *outages*.

A *connection agreement* may also state a conditional *power transfer capability* that allows for both circuits of a double circuit line or two closely parallel circuits to be out of service.

Appendix G Analysis of CBD Outage Incidents

G.1 Background

In 2001, CitiPower had two major events that resulted in loss of supply to the CBD.

The first event was in January 2001 and was the subject of an SKM report "Independent Review Following Loss of Supply incidents on 2 January 2001".

The second event was in November 2001 and was subject to a PB Power Report "Investigation into Electricity Supply Outage on 9 November 2001 Affecting Melbourne CBD"

G.2 Event on 2nd January 2001

Summary of Event

On the weekend of 31 December 2000, a 66kV feeder from WMTS to Zone Substation JA was taken out of service due to a low-pressure oil alarm. Supply to VM was maintained by the WMTS-VM2 66kV feeder. WMTS-VM3 66kV feeder was used to provide a second source of supply. Due to an unexpected increase in load, protection relays tripped on overload. The relay failed to indicate that overloading was the cause of tripping. Subsequent switching to restore supply resulted in an overload of a section of the remaining 66kV circuit to JA (WMTS-VM3 via sub W). This overloading exacerbated the condition of a cable that had been damaged at some undetermined time in the past, resulting in a trip and subsequent loss of supply to part of the CBD. Approximately 12,200 customers were affected for an average of 30 minutes.

Findings

A commentary on the incident and the findings of the ORG (now ESC) can be found on the ESC Website under "Draft decision on applications from financial incentives for supply reliability" July 2001.

The ESC did not accept CitiPower's application to exclude the event from S Factor calculations. The principal reason given was that the protection settings were not properly coordinated with the cable ratings leading to unnecessary tripping. With the increased network loadings now being experienced, the issue of incorrect settings for overload protection is now unimportant. The 2003 DSPR (page 37) indicates that this overloading problem still exists and requires "post contingency operational response to reduce load…." in the event of an outage. Thus, for the purposes of this report the ESC findings are not significant.

From a strategic planning perspective, more important findings are:

- The 66kV supply to JA did not have a true (N-1) capacity because the outage of one 66kV circuit resulted in an overload, under normal load conditions, of the remaining circuit. While this may not have been the case had the WMTS-VM2 protection not operated on incorrect overload settings, it is clear that the remaining cable was operating close to its capacity.
- It appears that CitiPower was constrained in providing a reasonable capacity alternative supply to JA due to fault level constraint issues.
- Switching of alternate supply sources was manual and restoration was therefore slower than could be achieved using remote switching via SCADA. For example, the switching of circuits from RTS to supply JA (via Sub W) took a significant time to complete and while this was taking place the VM-W 66kV cable failed.

Implications on Planning Criteria

- The N-1 criterion was satisfied, as no customers were lost due to initial cable outage.
- There was limited ability to restore N-1 capability following the planned cable outage (ie CitiPower was unable to restore the system to a "secure operating state").
- This inability placed approximately 30% of CitiPower's customers (12,200) at risk of losing supply for a further contingency.
- This inability also meant that over 100,000 people (apart from customers) were directly affected by loss of supply.
- CitiPower acknowledged that it would have required "uneconomic investment" in 66kV circuit breakers to mitigate the event.

This event demonstrates that the use of an (N-1) criterion in the CBD can lead to widespread interruptions. It is clear that this loss of supply event could have been avoided if either:

a) CitiPower had been able to properly return its network to a "secure operating state" or

b) CitiPower had an (N-2) planning criterion.

G.3 Event on 9th November 2001

Summary of Event

SPI PowerNet was installing a 4th 220/66kV transformer at WMTS. To enable the required works to be carried out, the No 3 220/66kV transformer was taken out of service. (This transformer was out of service for several days prior to the event.) As a result of a secondary control scheme failing to operate correctly the No 2 220/66kv transformer was disconnected, leaving the entire 66kV load being supplied by a single transformer. This transformer then tripped on overload, resulting in loss of supply to over 82,000 customers (total for both CitiPower and AGL). As WMTS supplies 50% of the CBD, it is estimated that a further 100,000 – 200,000 people in the CBD were directly affected by the event.

Findings

The ESC commented that the report into the event on 9th November "contained no suggestion that the actions of either CitiPower or AGL contributed to the incident". In addition, the ESC confirmed "that the outage could not be attributed to inadequate planning of transmission connection assets.

Despite the ruling that CitiPower did not contribute to the event, a number of findings are apparent:

- Even though there was a planned transformer outage for several days, the network operated in a "stable" state as opposed to a "secure" state; ie the network was unable to maintain supply in the event of a further outage. SKM believes that it was not physically possible to return the network to a “secure operating state” by means of load transfers to other Terminal Stations.

- Given the fact that extensive work was being carried out in West Melbourne Terminal Station, there was a significant possibility of accidental trips occurring on either of the remaining transformers.
- 50% of the CBD was supplied from WMTS, increasing the severity of the outage.

Implications on Planning Criteria

In a similar manner to the 2nd January event, this event demonstrates that the use of an (N-1) criteria in the CBD can lead to widespread interruptions.

It is clear that this loss of supply event could have been <u>avoided</u> if either:

a) CitiPower had been able to properly return its network to a “secure operating state” for the duration of the planned transformer outage.

or

b) CitiPower had a (N-2) planning criterion.

The impact of the event could have been <u>reduced</u> had there been either:

a) Better capability to transfer load away from WMTS to other Terminal Stations (by remote control)

Or

b) Less CBD load share supplied from WMTS (WMTS currently supplies approximately 50% CBD load).

G.4 Conclusions

a) Had the CBD network been designed to higher security standards (eg “N-1 Secure”), the CBD outages of 2nd January and 9th November could have been either avoided or reduced in severity. In both events, the prior outages took place a number of days before the loss of supply occurred. In other words, the CBD network was left in a “satisfactory operating state” (refer Section 4.1) for a significant period. Had the CitiPower CBD network been returned to a “secure operating state” (refer section 4.1) after each of the planned outages, it would have been in a position to cope with the subsequent forced outages. To achieve this outcome (ie achieve a higher security standard) would have required installation of 66kV circuit breakers at Zone Substations and 66kV ties between Terminal Stations.

b) Using customer numbers alone tends to hide the true impact of loss of supply events in the CBD. The number of people affected in a CBD outage can be up to 10 times larger than the number of customers affected.

c) The lack of transfer capacity on the 66kV network had a major impact on both the outage extent and outage duration.

d) In both incidents, an unstated but apparent contributing factor was the limitation imposed by fault level constraints. The fault level constraints prevented better use of the existing network, limited the use of load transfers and prevented the use of spare capacity at adjoining Terminal Stations.

e) Having WMTS supply almost 50% of the CBD load inherently increased the impact of an outage incident at WMTS. Reducing the reliance on any one supply point will automatically reduce the impact of a major outage.

Appendix H Glossary of Station Abbreviations

NOTE : Stations in Red are responsible for the CBD Supply

Abbreviation	Zone Substation	Abbreviation	Zone Substation
AP	Albert Park	**NT**	Newport (AGL Asset)
AR	Armadale	**MG**	Montague
B	Collingwood	**MP**	McIllwraith Place
BC	Balaclava	**NC**	Northcote
BK	Brunswick	**NR**	Nth Richmond
BSBQ	Bouverie St/ Queensberry	**PM**	Port Melbourne
C	Brunswick	**PR**	Prahran
CL	Camberwell	**Q**	Kew
CW	Collingwood	**R**	Richmond
DA	Dock Area	**RD**	Riversdale
DLF	Docklands Fishmans Bend (Powercor Asset)	**RP**	Russell Place
E	Fishermans Bend	**SK**	St Kilda
EW	Elwood (United Energy Asset)	**SM**	South Melbourne
F	Fitzroy	**SO**	South Melbourne
FB	Fishermans Bend	**TK**	Toorak
FR	Flinders/Ramsden	**TP**	Tavistock Place
FZ	Fitzroy (Site sold)	**VM**	Victoria Market
J	Spencer Street	**W (66kV Switching Station)**	Waratah Place
JA	Spencer Street (in Little Bourke Street)	**WA**	Celestial Avenue
L	Deepdene	**WB**	West Brunswick
LQ	Little Queen	**WG**	Westgate
LS	Lauren Street		

Abbreviation	Terminal Station (SPI PowerNet Asset)	Abbreviation	Terminal Station (SPI PowerNet Asset)
ATS	Altona	**KTS**	Keilor
BLTS	Brooklyn	**RTS**	Richmond
BTS	Brunswick	**WMTS**	West Melbourne
FBTS	Fishermans Bend	**YTS**	Yarraville (operated as AGL zone substation)

Appendix I Option 1 BSBQ 220/66kV

I.1 Description of Option 1 BSBQ 220/66kV

- Develop 220/66kV Terminal Station at BSBQ with 3 x 225MVA transformers.
- 220kV can be supplied by a number of means as follows:

  (a) BTS-RTS 220kV cable (cut into existing)

  (b) Installation of a 2nd BTS-RTS 220kV cable running via BSBQ. (This is the assumed 220kV supply).

  or

  (c) New 220kV loop (via cable) from WMTS (see cable route for scheme 5[42])

  Route could be approximately: **WMTS** - Macauley Road - O'Shanassy St - Courtney St - Queensberry St – **BSBQ**

- Existing BSBQ 22/11kV Zone Substation to be removed and replaced with new 66/11kV substation at BS supplied by 3 x 66kV 60MVA cables from the BSBQ TS with 3 x 30MVA 66/11kV transformers. (Note: 60MVA cables or similar have been chosen as they will have a smaller bending radius and therefore be easier to install than 120MVA cables).
- Install 3 x 66kV 120MVA cables between BSBQ and VM
- Transfer VM and WA load off WMTS (130MVA at Summer peak) and put onto BSBQ TS
- BSBQ 66/11kV to off-load VM and WA in the first instance with the three substations having a total installed capacity of approximately 270MVA.

A single line diagram of Option 1 is provided at the end of this Appendix.

I.2 Works at other sites

I.2.1 VM

- Fully switch VM using Gas insulated switchgear (GIS) using a "double bus" configuration
- Install 3 x 66kV 120MVA cables between BSBQ and VM (switched)

[42] Future Supply to the Melbourne City Council The Choice of Future Sub-Transmission Voltage

Transmission Development Department, SECV January 1976

- Rearrange Sub LQ feeders to bypass VM with capability of switching to VM if required.

I.2.2 WA

Rearrange No3 66kV cable supplying WA via loop into sub W. Change its connections such that the No3 cable and transformer at WA are fed directly from VM Bus No3. This will leave WA as a radially supplied substation from VM.

I.2.3 W

- Connect the two cables from No1 bus at Sub W directly to BSBQ. This will form a tie between BSBQ and RTS and with the other works described allow transfers of up to 240MVA between WMTS, RTS and BSBQ.
- Fully switch Sub W

I.2.4 FR

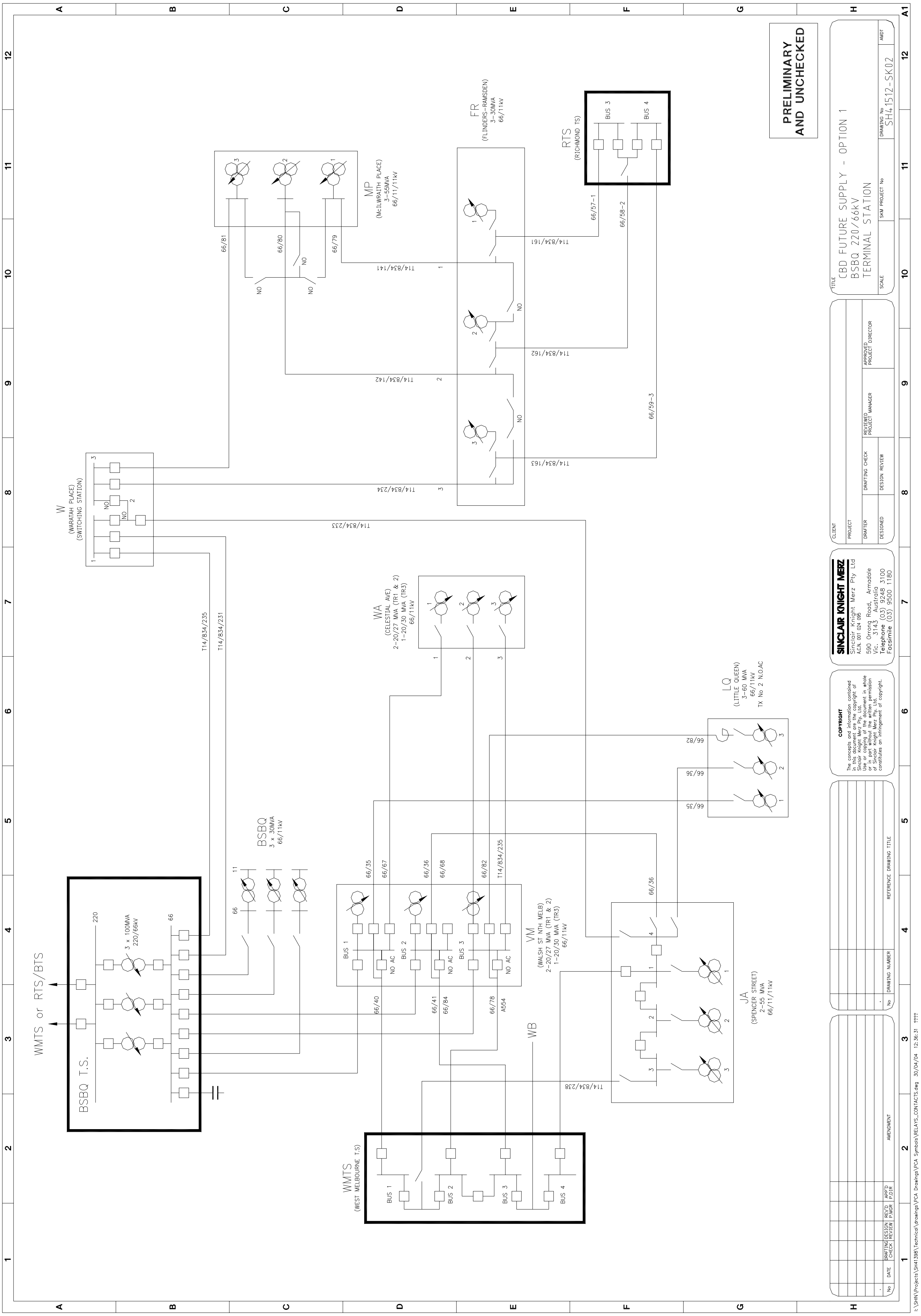
- Create new 66kV switch link between Bus 2 and Bus 3

I.3 Advantages of Option 1 BSBQ

- Shift VM and WA load away from WMTS. WMTS share of CBD load drops immediately from 49% to 35%. Total reduction in WMTS load (including non-CBD loads) could be as great as 131MVA in the summer peak.
- Released capacity at WMTS can be used to supply DA and JA.
- If proposed works at FR and W-FR 66kV are carried out, a transfer capability of 240MVA (via 2 x 66kV circuits) between RTS, BTS and WMTS can be achieved.
- Development works can be staged so that capacity augmentation matches load growth.
- Security of supply is to the CBD is dramatically improved as follows:
  - a) cable outages can only affect one transformer
  - b) transfers available between Terminal Stations allowing transfers to take place in the event of a prolonged 220/66kV transformer outage
  - c) Loading on existing Terminal Stations is reduced
  - d) 11kV transfers to BSBQ can remove risk of overload on VM (and WA later).
  - e) The next stage of 66/11kV transformer development would probably be Sub W. The proposed works will assist in this development.

I.4 Disadvantages of Option 1 BSBQ

- The BSBQ Terminal Station site will probably be limited in capacity to 3 x 225MVA transformers only. Thus the BSBQ development will only provide an additional 450MVA firm capacity into the CBD.
- There will be limited space to develop a 66/11kV Zone Substation at Sub BS. It is likely that the BS site could not accommodate transformers larger than 30MVA. Thus BSBQ 66/11kV substation would have a firm capacity of approximately 60MVA. This is the same as VM and WA.
- Need to establish 220kV cable supply into BSBQ site (from WMTS, existing BTS-RTS cable or new cable from BTS).
- Need to establish 3 x 66kV cable entries into VM (from BSBQ)
- Need to take BSBQ off line before re-development can begin.
- 220kV supply (from either BTS or WMTS) may be overloaded under some network conditions (eg high transfer on BTS-RTS 220kV cable or high loading on KTS-WMTS circuits) and reinforcement may be required. The ability to quickly and easily transfer over 200MVA of load between Terminal Stations (via the 66kV network) should alleviate this issue.



PRELIMINARY AND UNCHECKED
CBD FUTURE SUPPLY - OPTION 1
BSBQ 220/66kV
TERMINAL STATION
SH41512-SK02
SINCLAIR KNIGHT MERZ
Sinclair Knight Merz Pty Ltd
590 Orrong Road, Armadale
Vic. 3143 Australia
Telephone (03) 9248 3100
Facsimile (03) 9500 1180
COPYRIGHT
BSBQ T.S.
WMTS or RTS/BTS
3 x 100MVA
220/66kV
BSBQ
3 x 30MVA
66/11kV
WMTS
(WEST MELBOURNE T.S)
WB
VM
(WALSH ST NTH MELB)
2-20/27 MVA (TR1 & 2)
1-20/30 MVA (TR3)
66/11kV
JA
(SPENCER STREET)
2-55 MVA
66/11/11kV
LQ
(LITTLE QUEEN)
3-60 MVA
66/11kV
TX No 2 N.O.AC
WA
(CELESTIAL AVE)
2-20/27 MVA (TR1 & 2)
1-20/30 MVA (TR3)
66/11kV
W
(WARATAH PLACE)
(SWITCHING STATION)
MP
(McILWRAITH PLACE)
3-55MVA
66/11/11kV
FR
(FLINDERS-RAMSDEN)
3-30MVA
66/11kV
RTS
(RICHMOND TS)

Appendix J Option 2 BTS 220/66kV

J.1 Description of Option 2 BTS 220/66kV

- Develop 220/66kV Terminal Station at BTS with 4 x 225MVA transformers (firm capacity of 675 MVA). The 220kV supply to BTS exists in the form of:
  a) 2 x TTS-BTS 220kV overhead lines, each with a summer rating of 800MVA/2100Amp.
  b) BTS-RTS 220kV cable with rating of 400MVA

- Develop BSBQ 66/11kV substation. Two options are available:

  a) Existing **BS** 22/11kV Zone Substation to be removed and replaced with new 66/11kV substation 3 x 30MVA transformers supplied by 2 x 66kV 120MVA cables from the BTS and one 66kV 120MVA cable from VM.

  b) Existing **BQ** 22/11kV Zone Substation to be removed and replaced with new 66/11kV substation 3 x 60MVA transformers supplied by 2 x 66kV 120MVA cables from the BTS and one 66kV 120MVA cable from VM. **(This is the preferred option)**

- Install 2 x 66kV 120MVA cables between BTS and VM
- BSBQ 66/11kV to off-load VM and WA in the first instance with the three substations having a total firm (N-1) capacity of 300MVA (2x60MVA + 3x30MVA+ 3x30MVA)
- Transfer VM and WA load off WMTS and put onto BTS (At summer peak this will shift 130MVA from WMTS)
- Transfer WB-NC loop from WMTS to BTS but leave connections to WMTS intact for use in emergency situations. (At summer peak this will shift 46MVA from WMTS). Note: Old drawings indicate that this loop already crosses BTS boundary.
- Transfer CW-B-NR loop from RTS to BTS but leave connections to RTS intact for use in emergency situations (At summer peak this will shift 108MVA from RTS)

A single line diagram of Option 2 is provided at the end of this Appendix.

J.2 Works at other sites

J.2.1 VM

- Fully switch VM using Gas insulated switchgear (GIS). CitiPower has provided a slightly different option using a double-bus configuration that achieves the same purpose as the switching arrangement shown in the attached single line diagram.
- Install 2 x 66kV 120MVA cables between BTS and VM (switched)

- Install 1 x 66kV 120MVA cables between BSBQ and VM (switched)
- Rearrange Sub LQ feeders to bypass VM with capability of switching to VM if required.

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J.2.2 WA

Rearrange No3 66kV cable supplying WA via a loop into sub W. Change its connections such that the No3 cable and transformer at WA are fed directly from VM Bus No3. This will leave WA as a radially supplied substation from VM.

J.2.3 W

- Connect the two cables from No1 bus at Sub W directly to BSBQ. This will form a tie between BSBQ and RTS and with the other works described allow transfers of up to 240MVA between WMTS, RTS and BSBQ.
- Fully switch Sub W

J.2.4 FR

- Create new 66kV switch link between Bus 2 and Bus 3.

J.3 Advantages of Option 2 BTS 220/66kV

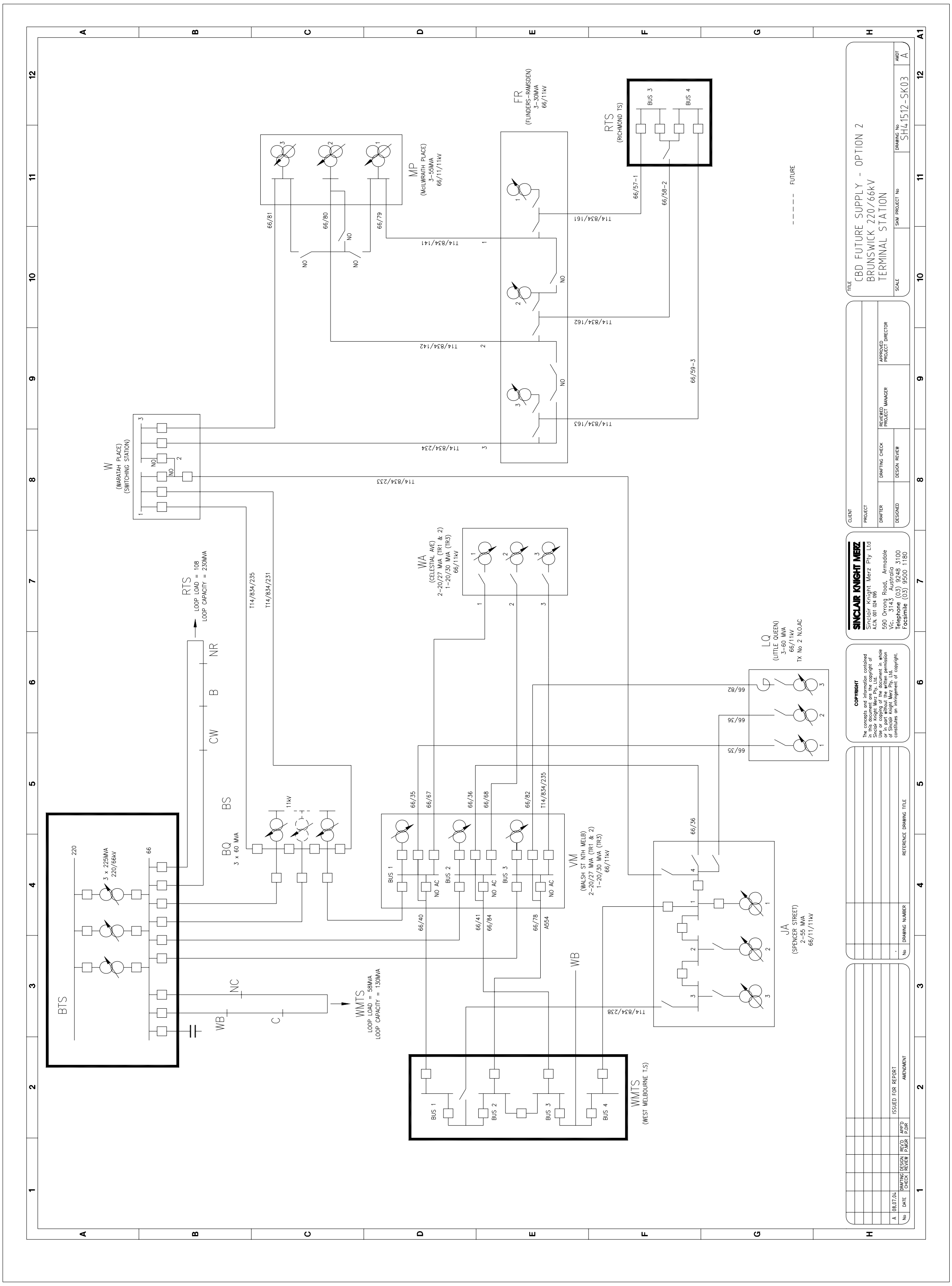
- Shift VM and WA load away from WMTS. WMTS share of CBD load drops immediately from 49% to 35%. Total reduction in WMTS load (including non-CBD loads) could be as great as 176MVA in the summer peak.
- Released capacity at WMTS can be used to supply DA and JA.
- The WB-NC 66kV loop can be readily shifted between WMTS and BTS, providing increased operational flexibility and allowing stations to be run above (N-1) capacity.
- The CW-B-NR 66kV loop can be readily shifted between RTS and BTS, providing increased operational flexibility and allowing stations to be run above (N-1) capacity.
- If proposed works at FR and W-FR 66kV are carried out, a transfer capability of 240MVA (via 2 x 66kV circuits) between RTS, BTS and WMTS can be achieved.
- Development works can be staged so that capacity augmentation matches load growth.
- Security of supply is to the CBD is dramatically improved as follows:
    f) cable outages can only affect one transformer
    g) transfers available between Terminal Stations allowing transfers to take place in the event of a prolonged 220/66kV transformer outage
    h) Loading on existing Terminal Stations is reduced

i) 11kV transfers to BSBQ can remove risk of overload on VM (and WA later).

j) The next stage of 66/11kV transformer development would probably be Sub W. The proposed works will assist in this development.

J.4 Disadvantages of BTS 220/66kV

- Development of a substation on the BQ site will preclude future use of the BQ site as a 220/66kV Terminal Station. (However it will allow higher capacity Zone Substation to be utilised).
- Need to establish 3 x 66kV cable entries into VM (two from BTS and one from BSBQ).
- Need to establish 4 x 66kV cables from BTS to the CBD (two to VM and two to BSBQ).
- Need to take BSBQ off line before re-development can begin.
- 220kV supply from TTS to BTS may be overloaded under some network conditions (eg high transfer on BTS-RTS 220kV cable) and reinforcement may be required. However, operational solutions are available including opening of the 220kV cable, transferring WB-NC loop to WMTS, transferring CW-B-NR loop to RTS and transferring SubVM and Sub WA back to WMTS.


CBD FUTURE SUPPLY - OPTION 2
BRUNSWICK 220/66kV
TERMINAL STATION
SH41512-SK03
SINCLAIR KNIGHT MERZ
BTS
WMTS
(WEST MELBOURNE T.S)
RTS
(RICHMOND TS)
JA
(SPENCER STREET)
VM
(WALSH ST NTH MELB)
WA
(CELESTAL AVE)
MP
(McILWRAITH PLACE)
FR
(FLINDERS-RAMSDEN)
W
(WARATAH PLACE)
(SWITCHING STATION)
LQ
(LITTLE QUEEN)
BQ
3 x 60 MVA
FUTURE
ISSUED FOR REPORT

SKM

Appendix K Initial Development Options

K.1 Option 1 BSBQ Terminal Station (3 x 225MVA 220/66kV)

Central CBD 220kV Option (BSBQ 220/66kV Terminal Station with 2x225MVA transformers)					Year	Category
Site	Works	Unit Cost ($2006)	Qty	Total Cost ($2006)		
BSBQ TS	Install new BTS-RTS 220kV cable running via BSBQ (Assuming cable installation is advanced by 20 years compared to VENCorp's plans)	$5,259,277	12	$44,860,824	2009	Shared Transmission Connection Asset
	Install 5x220kV GIS CBs	$2,997,788	5	$14,988,939	2009	Shared Transmission Connection Asset
	Station Refurbishment (220kV+ transformer civils+ 220kV & 66kV switchbay floors)	$15,000,000	1	$15,000,000	2009	Shared Transmission Connection Asset
	Control Room + comms/SCADA	$1,200,000	1	$1,200,000	2009	Shared Transmission Connection Asset
	Install 2 x 220/66kV 225MVA transformers (Allow room for ultimate 3 transformers)	$5,942,983	2	$11,885,966	2009	Demand Related
	Station Refurbishment (66kV)	$525,928	1	$525,928	2009	Demand Related
	Civil works for 66kV switchbay floor (per 66kV transformer)	$1,051,855	3	$3,155,566	2009	Demand Related
	Install 1 x 50MVAr 66kV Capacitor bank	$1,262,226	1	$1,262,226	2009	Demand Related
	Install 12x66kV GIS CBs -incl 1 initial cap bank CB (Allow room for ultimate 24x66kV GIS CBs)	$736,299	12	$8,835,585	2009	Demand Related
	Install 2x 66kV 120MVA cable from Sub W to BSBQ	$3,786,679	1.95	$7,384,025	2009	Security Enhancement
	Protection works for both ends of Sub W-BSBQ 66kV cables	$210,371	2	$420,742	2009	Security Enhancement
	Install 3x66kV 60MVA cables from BSBQ TS to Sub BSBQ	$3,786,679	0.05	$189,334	2009	Demand Related
	Protection works for both ends of BSBQ TS Sub BSBQ 66kV cables	$210,371	3	$631,113	2009	Demand Related
	Install 3 x 66kV 120MVA cables from BSBQ to VM	$5,680,019	1.95	$11,076,037	2011	Security Enhancement
	Protection works for both ends of BSBQ-VM 66kV cables	$210,371	3	$631,113	2011	Security Enhancement
	Re-direct VM-W feeder directly to Sub WA	$210,371	1	$210,371	2010	Security Enhancement
Sub BSBQ	Install 3x66/11kV 30MVA transformers + 11kV CBs & secondary works	$4,628,164	1	$4,628,164	2009	Demand Related
	Station Refurbishment (11kV)	$525,928	1	$525,928	2009	Demand Related
Sub VM	Replace 9x66kV isolators with 16 GIS CB's and isolators	$736,299	16	$11,780,780	2010	Security Enhancement
	Station Refurbishment	$1,051,855	1	$1,051,855	2010	Security Enhancement
Sub W	Replace 7 x 66kV isolators with 7GIS CB's + isolators with room for expansion to further 4 x 66kV CB's	$736,299	7	$5,154,091	2009	Security Enhancement
	Station Refurbishment	$1,051,855	1	$ 1,051,855	2009	Security Enhancement
Sub FR	Install additional 1x 66kV Link	$368,149	1	$368,149	2010	Security Enhancement
Sub MP	Install additional 1x 66kV Switch Link	$368,149	1	$368,149	2010	Security Enhancement
	Demand Related Reinforcement			**$31,639,809**		Note: Direct costs
	Security Enhancement			**$39,497,169**		Note: Direct costs
	Shared Transmission Asset/ Transmission Connection Asset Costs			**$76,049,763**		Note: Direct costs
			TOTAL	**$147,186,741**		

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K.2 Option 2 Brunswick TS (2 x 225MVA 220/66kV)

SKM CBD Report Appendix G Tables 2 & 3 UPDATE Option 2 (Brunswick 220/66kV Terminal Station with 2x225MVA transformers)					Year	Category
Site	**Works**	**Unit Cost ($)**	**Qty**	**Total Cost ($)**		
BTS	Install 2 x 220/66kV 225MVA transformers (including 3x220kV switchgear and 17x66kV GIS double bus CBs)	$33,000,000	1	$ 33,000,000	2009	Shared Transmission Connection Asset
	Install 1 x 50MVAr 66kV Capacitor bank	$1,262,226	1	$ 1,262,226	2009	Shared Transmission Connection Asset
	Install 1 x 66kV 120MVA cables from BTS to VM	$1,893,340	7.5	$ 14,200,047	2011	Security Enhancement
	Protection works for both ends of 66kV cable (BTS-VM)	$210,371	1	$ 210,371	2011	Security Enhancement
	Install 2 x 66kV 120MVA cables from BTS to BQ	$3,786,679	5.33	$ 20,183,001	2009	Demand Related
	Protection works for both ends of 66kV cables (BTS - BQ)	$210,371	2	$ 420,742	2009	Demand Related
Loop Costs	Connect Loop WB-C-NC at BTS (2 feeder cable terminations)	$105,186	1	$ 105,186	2009	Shared Transmission Connection Asset
	Connect Loop CW-B-NR at BTS (2 feeder cable terminations)	$105,186	1	$ 105,186	2009	Shared Transmission Connection Asset
	O/H 66kV line works for CW loop to BTS (2x4km)	$210,371	8	$ 1,682,969	2009	Shared Transmission Connection Asset
Sub BQ	Install 9 x 66kV CB's + isolators in Double bus configuration	$736,299	9	$ 6,626,689	2009	Demand Related
	Install 2 x 66/11kV 60MVA transformers + 11kV switchgear & secondary works	$5,259,277	1	$ 5,259,277	2009	Demand Related
	Civil works for switchbay floors (per 66kV transformer)	$1,051,855	3	$ 3,155,566	2009	Demand Related
	Station Refurbishment Costs for BQ	$1,167,559	1	$ 1,167,559	2009	Demand Related
	Install 2x 66kV 120MVA cable from BQ to sub VM	$3,786,679	1.95	$ 7,384,025	2011	Security Enhancement
	Protection works for both ends of 66kV cable (BQ-VM)	$210,371	2	$ 420,742	2011	Security Enhancement
Sub VM	Replace 9x66kV isolators with 19 GIS CB's and isolators (double bus configuration)	$736,299	19	$ 13,989,676	2010	Security Enhancement
	Station Refurbishment	$1,051,855	1	$ 1,051,855	2010	Security Enhancement
Sub W	Replace 7x66kV isolators with 7 GIS CBs + isolators (Allow room for ultimate 18x66kV GIS CB's + isolators)	$736,299	7	$ 5,154,091	2009	Security Enhancement
	Station Refurbishment	$1,051,855	1	$ 1,051,855	2009	Security Enhancement
	Install 2x66kV 120MVA cables from BQ to W.	$3,786,679	2.0	$ 7,573,359	2009	Security Enhancement
	Protection works for both ends of 66kV cable (BQ-W)	$210,371	2	$ 420,742	2009	Security Enhancement
Sub WA	Redirect VM-W feeder to Sub WA directly	$210,371	1	$ 210,371	2010	Security Enhancement
Sub FR	Install additional 1x 66kV Switch Link	$368,149	1	$ 368,149	2010	Security Enhancement
Sub MP	Install additional 1x 66kV Switch Link	$368,149	1	$ 368,149	2010	Security Enhancement
	Base Case: Demand Related Reinforcement			**$36,812,834**		Note: Direct costs
	Base Case: Security Enhancement			**$52,403,434**		Note: Direct costs
	Base Case: Shared Transmission Asset/Transmission Connection Asset Costs			**$36,155,567**		Note: Direct costs

TOTAL	**$125,371,835**

K.3 Common Works

Costs Common to Both Options - Security Enhancement

Site	Works	Unit Cost ($2006)	Qty	Total Cost ($2006)	Year
Sub VM	Replace 9x66kV isolators with 16 GIS CB's and isolators	$ 736,299	16	$ 11,780,780	2010
	Station Refurbishment	$ 1,051,855	1	$ 1,051,855	2010
Sub W	Replace 7 x 66kV isolators with 7GIS CB's + isolators with room for expansion to further 4 x 66kV CB's making use of GIS	$ 736,299	7	$ 5,154,091	2009
	Install 2x 66kV 120MVA cable from Sub W to BSBQ	$3,786,679	1.95	$7,384,025	2009
	Station Refurbishment	$ 1,051,855	1	$ 1,051,855	2009
Sub FR	Install additional 1x 66kV Link	$ 368,149	1	$ 368,149	2010
Sub MP	Install additional 1x 66kV Switch Link	$ 368,149	1	$ 368,149	2010
			Total	**$ 27,158,905**	

Appendix L Development Scenarios

L.1 Option 1 BSBQ

The costs and timings shown here are used in the NPV calculations.

BSBQ Option

Year		Connection Assets	Demand Related	Total (Connection + Demand) $M	Security Enhance $M
2007	BSBQ 2 x 225MVA 220/66kV and	$7.60	$3.16	**$10.77**	
2008	BSBQ 3 x 30MVA 66/11kV	$22.81	$25.31	**$48.13**	
2009	As above	$38.02	$3.16	**$41.19**	**$14.01**
2010	As above	$7.60		**$7.60**	**$13.78**
2011				**$0.00**	**$11.71**
2012					
2013	Sub W 2x60MVA 66/11kV	$9.36		**$9.36**	
2014					
2015					
2016					
2017					
2018					
2019	Sub W 1x60MVA 66/11kV	$4.42		**$4.42**	
2020	BSBQ TS 3rd 225MVA transformer	$10.00		**$10.00**	
2021					
2022	Zone Substation XXX 2 x 66/11kV 60MVA transformers	$9.36		**$9.36**	
2023					
2024					
2025					
2026					
2027	Zone Substation XXX 3rd 60MVA 66/11kV transformer	$2.63		**$2.63**	
2028	BTS 2 x 225MVA 220/66kV transformers + 4 x 66kV cables to New Zone Sub	$73.36		**$73.36**	
2029					
2030	2nd New Zone Substation 2 x 66/11kV 60MVA transformers	$9.26		**$9.26**	
2031					
2032	BTS 1 x 225MVA 220/66kV transformers + 4 x 66kV cables to New Zone Sub	$10.00		**$10.00**	

Note: Terminal Station Expenditure

L.2 Option 2 BTS (2x225MVA transformers)

The costs and timing shown here are used in the NPV calculations.

BTS Option

Year	Item	Connection Assets ($M)	Demand Related	Total (Connection + Demand) $M	Security Enhance ($M)
2007	BTS TS 2 x 225MVA 220/66kV &	$ 3.43	$3.68	**$ 7.11**	
2008	BSBQ ZS 2 x 60MVA 66/11kV	$ 10.28	$29.45	**$ 39.73**	
2009	as above	$ 18.08	$3.68	**$ 21.76**	**$14.20**
2010	as above	$ 3.43		**$ 3.43**	**$15.99**
2011				**$ -**	**$22.22**
2012					
2013	BSBQ 3rd 60MVA 66/11k/V Transformer		$ 4.42	**$ 4.42**	
2014					
2015					
2016					
2017					
2018					
2019	Sub W 2 x 66/11kV 60MVA transformers		$ 9.36	**$ 9.36**	
2020	BTS 3rd 225MVA transformer	$ 10.00		**$ 10.00**	
2021					
2022					
2023					
2024					
2025	Sub W 3rd 60MVA 66/11kV transformer		$ 4.42	**$ 4.42**	
2026					
2027					
2028	BTS 4th 225MVA transformer	$ 10.00		**$ 10.00**	
2029	New Zone Substation 2 x 66/11kV 60MVA transformers		$ 9.36	**$ 9.36**	
2030					
2031					
2032	New Terminal Station 2 x 225MVA transformers + 4 x 66kV cables	$ 73.36		**$ 73.36**	

Note: Terminal Station Expenditure

SKM

Appendix M NPV Evaluation of Development Scenarios

Comparison of PV costs of options over 25 years

	Option 2: Brunswick	Option 1: CBD	Difference CBD minus BTS
Capacity related	70.0	106.0	36.0
Security enhancement	37.6	28.8	-8.8
Total PV Costs with Security enhancement	**107.5**	**134.8**	**27.3**
Total PV Benefits of security enhancement	**41.2**	**41.2**	
NPV of security enhancement only	**3.6**	**12.4**	
Net PV of costs with security enhancement	**66.3**	**93.6**	

CBD option involves spending this much more on capacity

You spend this much less on security enhancement under the CBD option

Overall, the CBD option involves spending this much more

Notes re CBD option costs:

BTS to RTS cable advanced by 20 years (Input is cell M4 in "25 Year Exp and DCF" sheet)

BSBQ refurbishment costs = $15,000,000 (Input is cell C5 in "BSBQ 220kV Option" sheet)

Assumptions to be subject to sensitivity testing:

1. Effect on the timing of installation of the second 220 kV RTS-BTS cable of the BSBQ option
2. Effect on the timing of installation of the second 220 kV RTS-BTS cable of the BTS option
3. Cost of substation refurbishment at BSBQ (Option 1)
4. Reduction in unserved energy

Appendix N Reliability Targets

N.1 Comparison of Victorian Distribution Businesses

The table below sets out the annual targeted levels of reliability, by distributor, for the 2006-10 regulatory period.

	Network Type	Annual targeted levels of reliability, 2006-10 Unplanned interruptions SAIDI	SAIFI	Planned interruptions SAIDI	SAIFI	MAIFI
AGLE	Urban	73	1.27	6.0	0.03	0.8
	Short rural	113	2.25	14.0	0.08	2.6
CitiPower	CBD	14	0.25	5.9	0.02	0.03
	Urban	35	0.80	9.9	0.03	0.3
Powercor	Urban	98	1.63	16.0	0.09	1.5
	Short rural	118	1.80	35.0	0.15	3.1
	Long rural	297	3.30	70.0	0.25	9.0
SP AusNet[a]	Urban	109	1.82	16.0	0.09	3.5
	Short rural	185	2.73	35.0	0.15	4.0
	Long rural	300	4.28	70.0	0.30	10.8
United Energy	Urban	59	1.06	16.0	0.10	1.4
	Short rural	96	2.03	35.0	0.15	3.4

[a] Formerly TXU

Source: Essential Services Commission, *Electricity Distribution Price Review 2006-10: Final Decision Volume* 1, October 2005, Table 2.1: Annual targeted levels of reliability, by distributor, 2006-10 regulatory period.

N.2 Reliability Targets for CitiPower – including CBD Targets

The table on the following page sets out targeted levels of service reliability for CitiPower for the period from 2001 to 2010.

Network type	Measure	Targeted level of reliability 2001-05						Targeted level of reliability 2006-10				
		2001	2002	2003	2004	2005		2006	2007	2008	2009	2010
CBD	Unplanned SAIDI	16.0	15.9	15.8	15.6	15.5	Final Decision	14	14	14	14	14
	(minutes)						Distributor proposed	16	16	16	16	16
	Planned SAIDI	5.9	5.9	5.9	5.9	5.9	Final Decision	5.5	5.5	5.5	5.5	5.5
	(minutes)						Distributor proposed	5.9	5.9	5.9	5.9	5.9
	Total SAIDI	21.9	21.8	21.7	21.5	21.4	Final Decision	19.5	19.5	19.5	19.5	19.5
	(minutes)						Distributor proposed	21.9	21.9	21.9	21.9	21.9
	Unplanned SAIFI	0.25	0.25	0.25	0.25	0.25	Final Decision	0.25	0.25	0.25	0.25	0.25
							Distributor proposed	0.25	0.25	0.25	0.25	0.25
	Planned SAIFI	—	—	—	—	—	Final Decision	0.02	0.02	0.02	0.02	0.02
							Distributor proposed	0.02	0.02	0.02	0.02	0.02
	Unplanned CAIDI	63	63	63	63	63	Final Decision [a]	—	—	—	—	—
	(minutes)						Distributor proposed	—	—	—	—	—
	MAIFI	0	0	0	0	0	Final Decision	0.0	0.0	0.0	0.0	0.0
							Distributor proposed	0.0	0.0	0.0	0.0	0.0
	Calls answered within 30 secs	—	—	—	—	—	Final Decision	82%	82%	82%	82%	82%
							Distributor proposed	70%	70%	70%	70%	70%
	Number of overload events	—	—	—	—	—	Final Decision	0	0	0	0	0
							Distributor proposed	—	—	—	—	—
Urban	Unplanned SAIDI	56	51	46	40	35	Final Decision	35	35	35	35	35
	(minutes)						Distributor proposed	35	35	35	35	35
	Planned SAIDI	9.9	9.9	9.9	9.9	9.9	Final Decision	9.9	9.9	9.9	9.9	9.9
	(minutes)						Distributor proposed	9.9	9.9	9.9	9.9	9.9
	Total SAIDI	66	61	55	50	45	Final Decision	45	45	45	45	45
	(minutes)						Distributor proposed	45	45	45	45	45
	Unplanned SAIFI	0.95	0.92	0.89	0.85	0.80	Final Decision	0.80	0.80	0.80	0.80	0.80
							Distributor proposed	0.80	0.80	0.80	0.80	0.80
	Planned SAIFI	—	—	—	—	—	Final Decision	0.03	0.03	0.03	0.03	0.03
							Distributor proposed	0.03	0.03	0.03	0.03	0.03
	Unplanned CAIDI	59	55	51	48	44	Final Decision [a]	—	—	—	—	—
	(minutes)						Distributor proposed	—	—	—	—	—
	MAIFI	0.26	0.27	0.28	0.29	0.30	Final Decision	0.3	0.3	0.3	0.3	0.3
							Distributor proposed	0.3	0.3	0.3	0.3	0.3

Source: Essential Services Commission, *Electricity Distribution Price Review 2006-10: Final Decision Volume* 1, October 2005, Table D.21: Targeted levels of service reliability, 2001-05 targets, 2006-10 targeted levels — distributor proposed and Final Decision, CitiPower.

Appendix O Civil Costs for BQ Redevelopment

Sub BQ Cost Estimate for Station Redevelopment to 3 x 55MVA 66/11/11kV Transformation
Preliminary Report by Neil Meaden, SKM
July 14 2004

The BQ building requires the addition of another level to provide for 66kV plant/buses, 66kV cable terminations, capacitor banks and roof mounted transformer cooling towers and associated cold water common mixing basin. However, for the present level to which it is built, the building is pretty much complete from a civil perspective, provision being built in for almost all of the eventualities the ultimate electrical development of the station will demand.

With respect to the mezzanine level that presently accommodates a duplicate control room and is rather lavish with respect to utilisation of space, options exist for portion of the floor to be redeveloped for capacitor banks. The balance of the banks can be accommodated on the proposed additional floor in conjunction with the 66KV buswork, switching and cable terminations. This will need to be looked at in some detail should the project proceed to ensure with the type of 66KV switchgear being selected, sufficient space and access is available for the required number/capacity of cap banks to be located on that level. A worst case scenario might see the need for a further half floor level or part thereof to be created above the new 66KV floor.

The cost estimates provided below are for the non-mainstream items. It has been assumed that the obvious new electrical plant and associated full suite of secondary equipment, together with the required civil works to complete the additional floor level and one of the 11KV, 3- bus group floors have been separately taken into account. The items of this estimate are:

(a) Three roof mounted transformer cooling towers based on Maxiflow MXHTF/3/S model. (Supply and install)

&

(b) Transformer oil/water heat exchanger circulating cooling water systems, one per transformer, includes two circulating water pumps, a break tank, gal pipework, valves, flow meters, interconnection pipework facilities with adjacent transformer cooling systems. (Supply and install)

Estimated Total Cost for (a) & (b) **$400K**

(c) High-pressure water deluge fire suppression system zoned for each transformer with compressed air detection system and back up high-pressure booster water pump. (Supply and Install)

Estimated cost for (c). **$350K**

(d) Ducted circulating air system for substation including transformer bays **$50K.**

(e) Complete 415/240V rewiring of station based on duplicate supply sources with auto change over to service the water cooling and fire systems and general power and lighting requirements through out the station. Also including the special water proof array of light fittings in the transformer bays.
Estimated Cost: **$250K**

(f) Supply and installation of acoustic panels in the transformer bays **$60K**

Total Cost: $1,110K

Other Observations:

- The station drain tank for transformer oil spills and fire system water exists.
- The blast walls for all transformers exist in the form of double brick walls. These walls will have to be removed/rebuilt in turn to permit access for the new transformers.
- The transformer enclosure walls on four sides of each transformer bay exist and form the bunding system.

Most of the above cost figures are based on upgraded estimates obtained for the third JA transformer installation (when originally proposed 2 years ago) with some allowance for CPI adjustment and site conditions.