TRANSPOWER

OTAHUHU SUBSTATION DIVERSITY PROJECT

PROPOSAL

APPLICATION FOR APPROVAL

11 DECEMBER 2006

Contents

Attachments

Summary

This document represents Transpower's proposal for the Otahuhu Substation Diversity Project.

The Works

The following works make up Transpower's Otahuhu substation diversity proposal for which Transpower is now seeking approval:

- Remove all over-crossings of the existing substation at Otahuhu
- Install bus section circuit breakers in the existing 220 kV switchyard
- Procure, construct, commission and operate a new 220 kV GIS switchyard and a new AIS switchyard at Otahuhu, connected and adjacent to, but geographically separated from, the existing switchyard
- Transfer approximately half of the circuits from the existing switchyard to the new switchyards
- Obtain designations, and resource consents necessary for the above
- Plan for commissioning of the new switchyard by 2009.

Costs

Transpower is seeking Electricity Commission approval for costs incurred by Transpower in the implementation of the proposal. The estimated capital cost for the amended proposal is $83m in $2006, including contingencies ($75m excluding contingencies).

Category	Estimated Cost $m (2006)	Estimated Cost including Contingencies $m (2006)
Design	1	1
Enabling Works	7	8
Substation Works – AIS	7	8
Substation Works - GIS	30	33
Transmission Lines/Cabling	24	27
Project Management	6	6
Total	**75**	**83**

Table 0-1: Proposal Costs

Rule Requirements

Transpower considers the Proposal as described above meets the requirements of the Rules in that:

The Proposal meets the Grid Reliability Standards (GRS).

Specifically, it satisfies both Clause 4.1 and 4.2 of the GRS and is classified as an economic reliability investment.

The Proposal complies with the Rule processes

Transpower considers that the Amended Proposal follows the processes set out in Section III, Part F of the Electricity Governance Rules.

The Proposal satisfies the Grid Investment Test

Under the Grid Investment Test, the Proposal has a net market cost that is $1.8 million lower than the alternative option.

Timing

The timing for this project is determined by how quickly it can be implemented. Delivery time is estimated at two years from the approval date.

Transpower has not discussed an approval programme with the Commission. However, as this is a re-submission of the project, it is hoped that final approval could be forthcoming no later than the end of February 2007, which would result in a commissioning date of early 2009 for the new switchyards.

Comparison of Benefits

Application of the grid investment test shows that the AIS and GIS development options are both NPV positive when compared to the reference case, with the building of a new GIS switchyard being the most economic option by $1.8 million.

This differential may be considered as negligible when compared to the total net present values of the options of circa $55 million each, therefore the other benefits of option 3 should play a major role in the decision over which development option to proceed with.

The benefits of option 3 (GIS) that are not included in the economic investment test, but are still quantifiable include:

- Property costs. For the reference case and option 2 the cost of new land required to replace the existing switchyard in the future is estimated at $7.7 million
- Immunity to site wide, high impact, low probability events (e.g. severe weather that affects all exposed switchgear and bus work). The annualised NPV of this is estimated at $1 million

Taking these benefits into account will increase the economic advantage of the GIS option over the AIS option from $1.8 million to $10.5 million.

A comparison of the options is presented in the table below:

	Option considered		
Comparison criterion	Reference case: Develop existing substation	Option 2: Establish new AIS switchyard	Option 3: Establish new GIS facility
GRS compliance	Yes	Yes	Yes
Electrical diversity	No	Yes	Yes
Implementation risk	High	Low	Low
GPS compliance (s80)	No	Partly	Yes
Geographical diversity	No	Limited	Yes
Effect on business confidence	No change	Improves	Best
Consenting risk	High	Highest	Low
Options for the future	No	No	Yes

Table 0-2: Comparison of Otahuhu substation reliability improvement options

Recommendation

It is recommended that the Commission approve the Proposal to build a new GIS switchyard at Otahuhu as per option 3, on the grounds that it:

- meets the GRS
- is consistent with the objectives of the GPS
- complies with the Rules
- passes the GIT
- is consistent with GEIP
- provides clear advantages over the alternative with respect to:
    - property costs for long term development plans
    - immunity to site wide events
    - consenting issues

1 Introduction

1.1. Purpose

The purpose of the Otahuhu Substation Diversity Project is to diversify and improve the reliability of supply into Auckland and Northland.

The purpose of this document is to obtain approval from the Electricity Commission to undertake this upgrade, and for the recovery of the cost from doing so.

All references to rules in this document refer to those in Section III of Part F of the Electricity Governance Rules (EGR's), unless specified otherwise.

1.2. Background to this Proposal

Transpower has recognised an issue with the reliability of transmission through the existing 220 kV Otahuhu substation. Most of the power supplied into the upper North Island, including Auckland and Northland, flows through Otahuhu substation, and its reliability is of critical importance to these areas. Furthermore, a major failure at Otahuhu could credibly result in voltage collapse that would affect most of the North Island from Whakamaru northwards, and possibly further south.

Transpower's Otahuhu substation is a legacy asset, having developed incrementally over the past 50 years. Although there have been a number of security upgrades over the years, such as the addition of bus zone protection and bus coupler circuit breakers to help mitigate the impact of failures, it remains a basic single-breaker double-bus design, that is not considered under good electrical industry practice to be appropriate for the level of power being transferred through the substation.

Some of the historical developments have resulted in transmission lines crossing over both the 110 kV and 220 kV switchyards at the substation. These 'over crossings' are not unusual in an 'industry practice' context but are considered to be undesirable from the perspective of a critical substation because of the risk posed by falling conductors – a rare but high consequence event.

Recent events at Otahuhu have highlighted the vulnerability of the existing switchyard to low probability, high consequence events. Although by definition, these events are rare, they are also highly unpredictable and can have a major impact on supplies to consumers. In the probabilistic planning context, it is not always feasible to enumerate each and every event that could lead to a high impact event. The probability of a high impact event is thus always higher than an enumerated approach to reliability assessment.

Transpower proposes to address the vulnerability issues and improve the reliability of the 220 kV Otahuhu substation by building a new 220 kV switchgear facility on the same site, but physically and geographically separated from the existing switchyard. Existing and new circuit connections will be diversified between the two switchyards so that a major failure in one of the switchyards will not result in a total loss of supply via Otahuhu substations. The flexibility offered by two independent substations will also improve the flexibility and operational options available to restore supplies in the event of major loss of load event.

The proposal to build a new 220 kV switchyard, and diversify connections was first proposed in Transpower's initial 400 kV Investment Proposal dated 13 June 2005. The 'North Island 400 kV Upgrade Project Investment Proposal' recommended that "the existing 220 kV circuits … will be rearranged so that key loads are supplied from both the existing and new 220 kV busses to achieve diversity". The current proposal is wholly consistent with this recommendation.

2 Grid Upgrade Plan

On 11 August 2006 Transpower submitted an Interim Grid Expenditure request to the Commission seeking approval for funds to build a new GIS switchyard at Otahuhu. This IGE request did not gain formal approval from the Commission. This request is now being re-submitted as Volume V of Transpower's first Grid Upgrade Plan. The first volumes of this GUP were submitted on 30 September 2005.

Rule 12.3 sets out the required contents of a GUP.

Rules 12.3.1 and 12.3.2 require that a comprehensive plan for asset management and operation of the grid, and information on investment contracts, be included. Transpower refers the Commission to the Asset Management Plan and list of investment contracts that were submitted to the Commission in Volume 1 of the first GUP, dated 30 September 2005.

The Otahuhu Substation Upgrade proposal, as set out in Section 9 of this application, describes the proposed reliability investment as per Rule 12.3.3.

Section 10 of this document demonstrates that this GUP complies with the requirements of the EGRs.

3 Wider development context

3.1 North Island Grid Upgrade Project

The proposal to build a new substation at Otahuhu stands independently of the proposed North Island Grid Upgrade Project. This is because even with the new line terminating at Pakuranga, there will remain a large portion of load supplied via Otahuhu, hence it is considered prudent to improve the reliability and diversity at Otahuhu irrespective of the other project.

An additional consideration is the issue of timing and risk. Providing diversity through the building of new transmission capacity into Pakuranga will take in the order of five or six years. The almost complete dependence on Otahuhu will exist for this period of time. Building a new, reliable substation at Otahuhu provides electrical and physical diversity and can be accomplished in the much shorter period of two years.

For the purposes of this submission, it is assumed that Transpower's proposed major upgrade to the Auckland region, or an equivalent, will ultimately be approved by the Commission and proceed.

It is also assumed that the works required under the North Island Grid Upgrade Project are commissioned by the 'needs' date, that is, by the time that the system requires them. This in effect provides an allowance for project implementation risk by assuming the worst case situation with respect to project timing.

3.2 North Auckland and Northland Upgrade Project

For the purposes of this submission, it is assumed that the North Auckland and Northland Upgrade Project will proceed. This project is at the 'Request for Information' stage and has yet to be submitted to the Commission. All options under consideration for the North Auckland and Northland Upgrade Project involve two additional 220 kV outgoing lines from Otahuhu by about 2012 or 2013. These will either be as new cables directly to Penrose, or via Pakuranga on a combination of existing and new transmission lines / cables.

4 Needs Assessment

This project is needed to improve reliability of supply into the greater Auckland area, North Auckland and Northland. The supply to all of these areas is and will remain heavily reliant on the reliable operation of Otahuhu substation. A major failure at Otahuhu substation could credibly result in a voltage collapse that would affect the North Island from Whakamaru northwards. The arrangements at Otahuhu are thus critical for the future supply reliability in the North Island.

At present, Otahuhu substation does not meet the requirements of the power system in the following areas:

4.1 Grid Reliability Standards

The existing substation does not meet the Grid Reliability Standard.

Clause 4.2 of the GRS requires the power system to remain in a satisfactory state during a single contingency event, including the loss of a bus section. The existing switchyard has an exposure to a single busbar fault that will remove two major transmission items from service as illustrated in Figure 4-1. Such an event could have a significant impact on the power system, and may result in widespread loss of supply for a single credible initiating event.

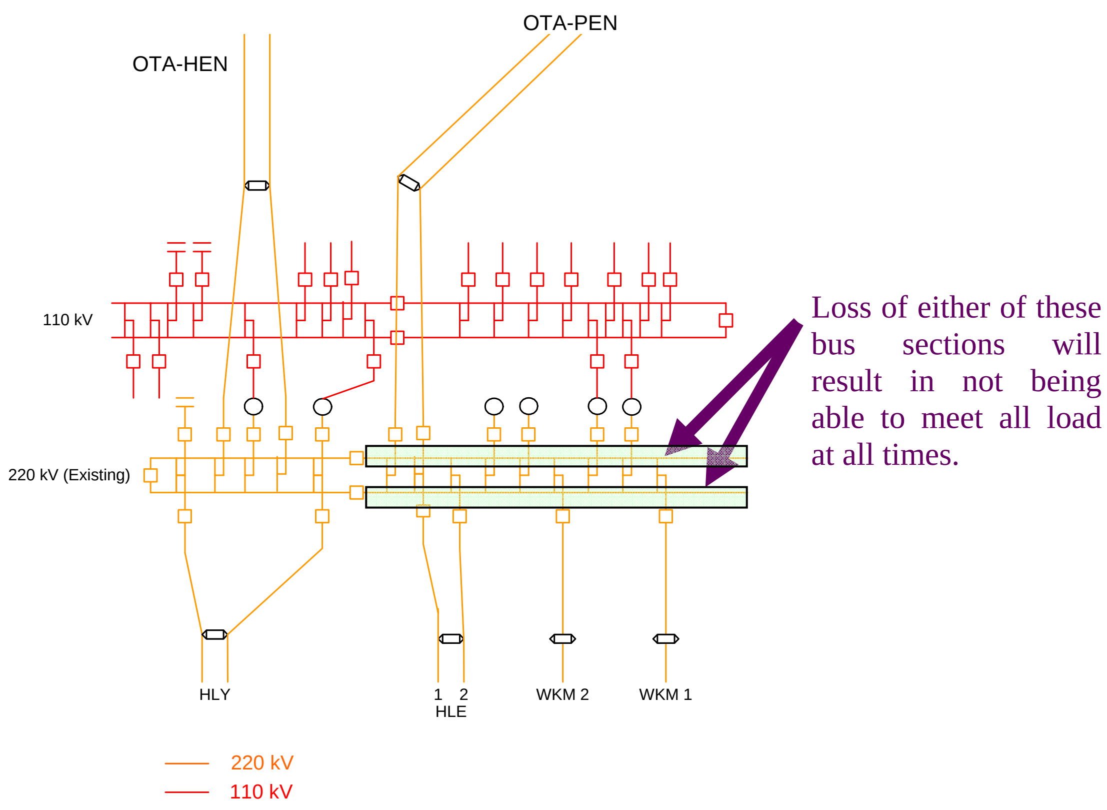

Figure 4-1: Existing substation showing vulnerability to bus section faults

4.2 Over-crossings

The outage earlier this year (June 12 2006) at Otahuhu substation which resulted in a loss of supply to most of Auckland was caused by the failure of an overhead earth wire crossing over the existing AIS switchyard. This event illustrated the criticality of the existing substation in its present configuration. The government's independent report on the failure (the Connell Wagner report) recommends the removal of all crossovers, requiring cabling of some feeder entry and exit points.

Although over-crossings of earth-wires and busbar conductors are not unusual in industry practice, Transpower agrees with the Connell Wagner report that, given the criticality of the Otahuhu Substation, measures such as removing over-crossings should be undertaken to eliminate risks of further events related to falling conductors.

4.3 Switchgear configuration

The existing 220 kV switchyard is built in a configuration referred to as a single-breaker double-bus. This configuration is no longer considered as suitable for major substations such as Otahuhu due to its inherently lower reliability when compared to other switchyard configurations such as double-breaker double-bus or 1.5 circuit breaker configurations.

Industry practice is for major new substations to be built to at least a 1.5 circuit breaker configuration or to have high reliability technology, such as indoor gas insulated technology, for implementations of single-breaker double-bus configurations. It is noted that recent substation refurbishments internationally, such as at Yass in the New South Wales transmission grid, also tend towards high reliability solutions like 1.5 circuit breaker configurations.

4.4 Future expansion requirements

The existing 220 kV switchyard has been expanded since its original commissioning in the 1950's to the point where there is very limited space available for adding further circuit breaker bays to the existing busbar in its present configuration. The control room and crane house are in the way of further expansion of the switchyard to the east, and the western end of the switchyard is already on the site boundary, adjacent to a road.

4.5 Double-up of circuit breaker bays

Due to the constraints on available space for expansion of the existing substation, Transpower has been forced into 'doubling up' several circuit breaker bays at Otahuhu. A consequence of these double-ups is a reduction in reliability due to the failure of a single disconnector or circuit breaker removing from service both connected lines or elements. This may be tolerated if the two elements are a feeder and a capacitor bank or transformer, but at Otahuhu, there is a double-up on two major feeder circuits, the Otahuhu – Whakamaru and Otahuhu – Penrose circuits. This is not a desirable situation for a major substation, as the loss of these two feeders will have a major impact on the power system at times of high load and could credibly require load reductions in order to maintain security of the power system

4.6 Diversity of supplies

Good industry practice for power system design is to limit the amount of power being transmitted through individual switchyards. The rationale behind this practice lies with mitigating the effects of low probability, high consequence events that can (and do) occasionally result in the loss of entire switchyards. This is especially valid in switchyards such as Otahuhu that supply nationally important loads like Auckland and the entire top of the North Island.

As an example of international practice, National Grid UK requires more than one terminal station for loads greater than 1500MW.[1] The peak load supplied through Otahuhu is presently around 2200 MW and will remain at or above 1500 MW for many years in the future, even with the reinforcement of Pakuranga substation with the proposed new transmission line.

[1] GB Security and Quality of Supply Standard, 2004; www.nationalgrid.com

5 Existing System

Auckland is primarily supplied from the south through western and central paths.

- The western path consists of three 220 kV circuits from Huntly to Otahuhu.
- The central path consists of three 220 kV circuits from Whakamaru to Otahuhu.

All these circuits pass through the Otahuhu 220 kV bus. Auckland is also supplied by two 110 kV circuits from Bombay and a 110 kV circuit from Arapuni. However, their contribution is significantly lower than the 220 kV circuits.

The existing configuration of the Otahuhu substation is shown in Figure 5-1.

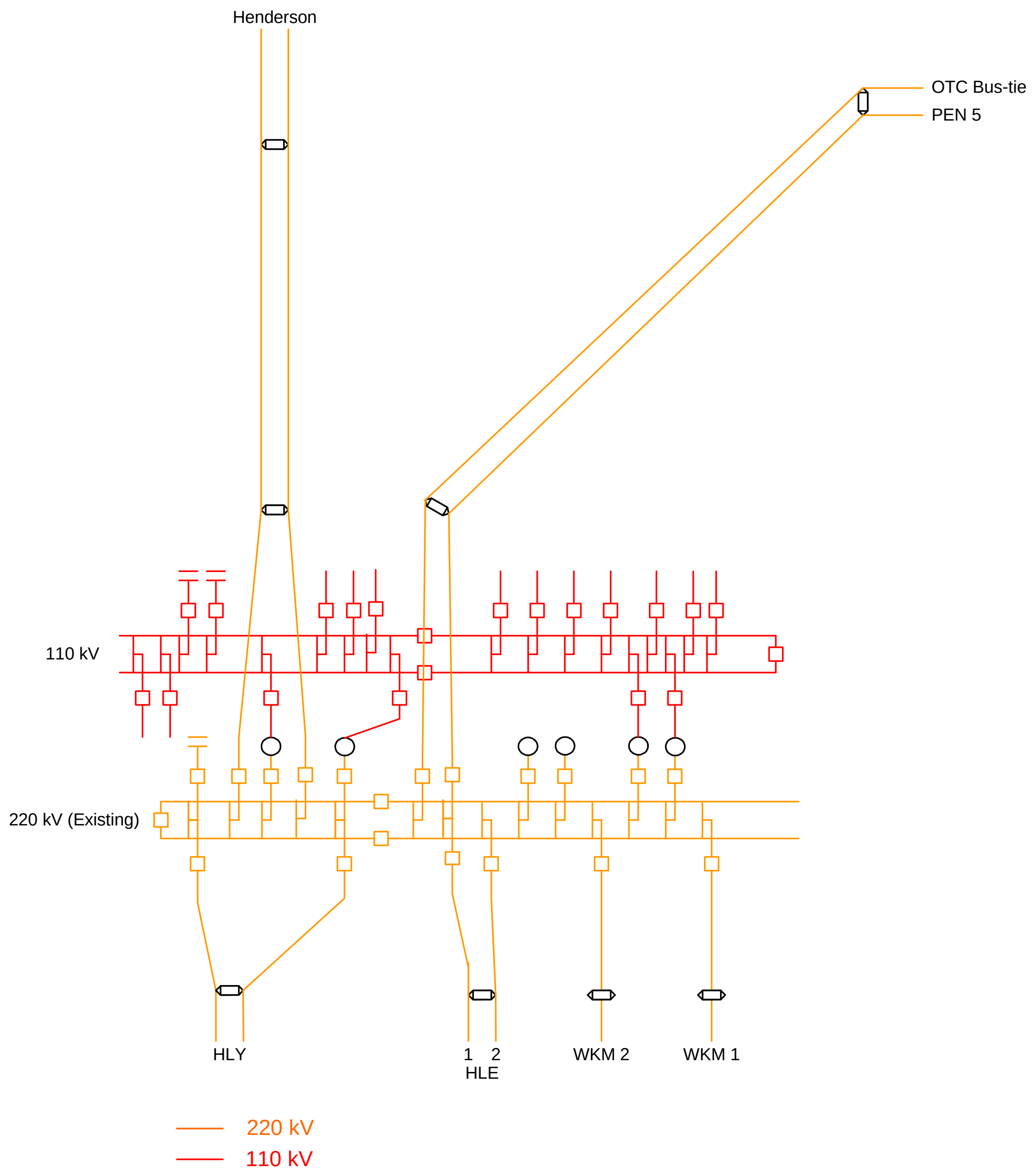

Figure 5-1: Existing configuration at Otahuhu Substation

(110 kV lines omitted for clarity)

5.1 Future Expansion Requirements

Table 5-1 lists the future expansion requirements for Otahuhu substation. This list is derived from the amended North Island Grid Upgrade Proposal, which includes all developments for the Auckland region over the next 35 years.

Year	Augmentation	OTA connections
2009	Install 250 MVAr static reactive plant at Otahuhu (note 1)	2
2010	Install 100 MVAr static reactive plant at Otahuhu (Hepburn) [2]	~~1~~
2013	Increase operating voltage of Otahuhu -Pakuranga to 220 kV	2
2016	Install 100 MVAr static reactive plant at Otahuhu (Penrose) [2]	~~1~~
2017	Install 100 MVAr static reactive plant at Otahuhu (Penrose) [2]	~~1~~
2018	Install 100 MVAr dynamic reactive plant at Otahuhu	1
2022	1 x 220 kV Penrose - Otahuhu cable	1
2022	1 x 220 kV Transition Station - Otahuhu cable	1
2024	Install 200 MVAr static reactive plant at Otahuhu [1] (Black Hill) [2]	~~2~~
2024	Second 220 kV Otahuhu - Transition Station cable	1
2025	Install 100 MVAr dynamic reactive plant at Otahuhu	1
2029	Install 150 MVAr static reactive plant at Otahuhu	1
2032	Install 300 MVAr dynamic reactive plant at Otahuhu	1
2033	Install 150 MVAr static reactive plant at Otahuhu (Pakuranga) [2]	~~1~~
2034	Second 220 kV Penrose-Otahuhu cable	1
2038	New Otahuhu 220/110 kV transformer in parallel with T3 and T5	1
2042	Install 300 MVAr static reactive plant at Otahuhu [1]	2
	Total new connections required at Otahuhu	**15**

Notes:

1. Assume static caps per CB is limited to a maximum of 150 MVAr.
2. This reactive plant may be moved to nearby substations as indicated, subject to a detailed design analysis

Table 5-1: Additional 220 kV Circuit breakers required at Otahuhu substation from 2006 to 2042

As illustrated in Table 5-1, there is a need for a considerable number of additional connections into and out of Otahuhu substation. Over the next 35 years at least 15 new connections will be required.

6 Assumptions

6.1 Major failures and circuit breaker reliability

The type of failure having the greatest impact on supplies into Otahuhu and Auckland is the loss of incoming 'feeder' circuits from the south. The power system is designed to withstand the loss of one feeder, but not two simultaneously. This contingency event (i.e. the loss of two feeders from the south) is therefore considered as a loss of load event in all subsequent analysis.

This is an N-2 event and it could result in the loss of load to the upper North Island either through thermal constraints on the remaining feeders, or as the result of voltage instability. Further discussion on N-2 events into Otahuhu substation can be found in Attachment D of Transpower's North Island Grid Development Amended Proposal, October 2006.

Note that for the purposes of this and subsequent analysis, the OTA-WKM A & B lines are regarded as a single incoming feeder due to their combined capacities being approximately equal to that of each of the other incoming 220 kV circuits.

Of all the single contingency events that could result in the loss of two feeders from the south, a bus coupler or bus section circuit breaker failure is the worst. This is because, should such a circuit breaker fail in a way that results in the tripping of connected equipment (i.e. the busses either side of the circuit breaker), then two bus sections will be tripped.

It should be noted that a bus circuit breaker failure is not regarded under the EGR's as a 'credible single contingency event', therefore the impact of this type of event is assessed under Rule 4.1, the probabilistic limb of the GRS. Transpower understands that the Commission requires consideration of BOTH Clause 4.2 and 4.1 in any reliability augmentation. The assessment of economic benefits under Clause 4.1 is thus mandatory and forms the basis of a wider investigation into the longer term requirements and performance of the Otahuhu substation and the development options.

Economic benefits under Clause 4.1 arise from the ability to 'rescue' expected unserved energy arising from the low probability events associated with failures that are not defined in the EGRs as 'credible'. This is a major plank of the Commission's interpretation of the GRS and arguments have been presented that imply that assessments of benefits arising from probabilistic analysis under Clause 4.1 could be used to justify investments that deliver reliability in excess of the so-called safety net arrangements of n-1 in Clause 4.2. Transpower has therefore assessed the economic benefits under Clause 4.1 of avoiding the low probability events that might result in the loss of two bus sections at Otahuhu substation.

Based on circuit breaker failure data compiled and published by CIGRE2, the probability of a major failure of a 220 kV AIS circuit breaker such as those installed in the existing switchyard is approximately 0.0258 per year per circuit breaker. Further analysis of the data shows that approximately 16% of these major failures will result in the tripping of all equipment connected to the circuit breaker. This translates to once every 250 years for each circuit breaker. This is in broad agreement with

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[2] CIGRE WG13.06, report number 83. Final report of the second international enquiry on high voltage circuit-breaker failures and defects in service. CIGRE, June 1994.

historical circuit breaker failure data gained from Transpower's records as shown in Appendix B.

This analysis is less pessimistic than the earlier analysis presented in Transpower's Interim Grid Expenditure application where the failure rate of 0.0258 was used to assess the consequences of losing two bus sections. Transpower notes that one of the main issues with probabilistic based assessments of economic benefits is the lack of relevant statistics and the variances associated with the statistics that are available. Nevertheless, Transpower believes the current approach is the best estimate for the particular event under consideration.

Caution is also urged in the consideration of the probabilistic approach. Transpower has not considered all low probability events that could be associated with, for example:

- Failure of isolators, particularly when transferring feeders from one busbar to another;
- Circuit breakers that fail to open when required, resulting in consequential protection action ('stuck breaker' events); and
- Other failures (damage to cable trenches, civil issues requiring de-energisation of multiple bus sections, protection mal-operations etc).

Consideration of ALL potential failure modes, even if they could be enumerated, would increase the levels of expected unserved energy above the levels estimated for this assessment of Clause 4.1 economic benefits.

6.2 Impact of a major failure

As described above, should a bus coupler or bus section circuit breaker fail in the existing switchyard, there is the possibility that supply to the upper North Island would be lost which could cause subsequent cascade failure resulting in lost load in all areas north of Whakamaru. It is the cost of this unserved energy that plays a major role in the economic analysis of the options.

The following cases are considered in the economic analysis:

- worst case - lost load includes load north of Whakamaru including Bay of Plenty;
- best case - lost load is confined to Otahuhu and north;

The System Operator provided indicative duration times for such outages resulting from a compete loss of load. These were estimated under a best and worst case as illustrated in Table 6-1.

Extent of outage	Duration of outage (hours)	
	Worst Case	Best Case
Whakamaru north (including the Bay of Plenty)	10	8
Upper North Island	7	5

Table 6-1: Estimated outage times resulting from Otahuhu substation failure prior to sectionalising and diversifying the existing switchyard

It should be noted that the forward looking outage rates of the circuit breakers are based on the amount of time the system will be out for – i.e. the impact of a failure, as opposed to the outage of the circuit breaker in isolation. The circuit breaker itself may be restored sooner or later depending on the cause of failure. However, it is the impact that is of concern in the reliability analysis.

For all options, sectionalising of the existing switchyard occurs in 2009. For options 2 and 3, diversification occurs at the same time (2009) thereby reducing the risk of unserved energy for these options to nothing. However, diversification for the reference case does not occur until 2013, therefore it remains exposed to the high risk of unserved energy until that time.

This is detailed in the tables below:

	Existing switchyard sectionalised	Southern circuits diversified
Reference case	2009	2013
Option 2	2009	2009
Option 3	2009	2009

Table 6-2: Milestone dates used for calculation of unserved energy

	2007	2008	2009	2010	2011	2012	2013	2014 on
Reference case	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Option 2 (AIS)	Yes	Yes	No	No	No	No	No	No
Option 3 (GIS)	Yes	Yes	No	No	No	No	No	No

Yes = Risk of unserved energy based on outages as per table 6-1

No = No risk of unserved energy following a bus section circuit breaker failure

Table 6-3: Exposure to risk of unserved energy following a bus section circuit breaker failure

7 Options Considered

As the transmission network grows in the upper North Island, Otahuhu substation will need to be expanded to accommodate a number of new circuits and equipment circuit breakers (refer to Table 5-1). The need for this growth is not the subject of this application as it is covered in the North Island Grid Upgrade Project submitted in October 2006. This proposal focuses on the best way to accommodate the projected growth, while at the same time improving diversity at Otahuhu substation.

Otahuhu substation could continue to be developed in much the same way as it has over the previous 50 or so years, namely by adding new equipment into the existing switchyard to achieve the short term goals of various other projects.

Alternatively, an opportunity presents itself at this juncture to evaluate development paths for Otahuhu substation that:

- improve reliability and reduce expected unserved energy;
- improve diversity; and
- meet the defined future requirements.

Transpower's development options that have been identified for Otahuhu fall into two broad categories:

- Continued development of the existing substation (reference case)
- Building a second, new switchyard at Otahuhu (options 2 and 3)

The options are described in detail below.

7.1 Reference case: Modify and extend the existing substation

This case entails a 'quick fix' to address some of the immediate (and severe) problems at Otahuhu, followed by a staged expansion of the existing substation as described below:

Works required immediately (2009):

- remove all crossovers of the existing switchyard and cable relevant feeder entry and exit points. Crossovers are removed by installing underground cables from the 'termination' towers of the overhead lines as they enter the substation, to the switchgear equipment itself; and
- add bus sections to the existing switchyard. This involves adding four new 220 kV bus section circuit breakers to the existing switchyard.

Future developments:

Build an air insulated switchgear (AIS) switchyard extension to accommodate additional circuits and reactive support. This would include:

- building a 1.5 circuit breaker extension located to the south of the existing switchyard to accommodate additional circuits and feeders that are required at Otahuhu;
- removing double-ups in the existing switchyard;

- diversifying existing and new circuits between the existing switchyard and the bus extension; and
- building a single-breaker double-bus switchyard extension located to the north of the existing switchyard. This will accommodate the additional reactive support required at Otahuhu.

The different configurations are chosen to reflect the reliability requirements of the additional equipment to be connected at Otahuhu. The 1.5 circuit breaker configuration has a higher reliability than single-breaker double-bus (SBDB) configuration and hence is used for additional feeders and circuit connections. The SBDB configuration has an adequate reliability for reactive support, and is more cost effective in this type of application than a 1.5 circuit breaker configuration.

The switchyard would continue to be extended to accommodate additional circuits and reactive support required over the next 35 plus years at this substation.

A single line diagram of the reference case is provided in Appendix A.

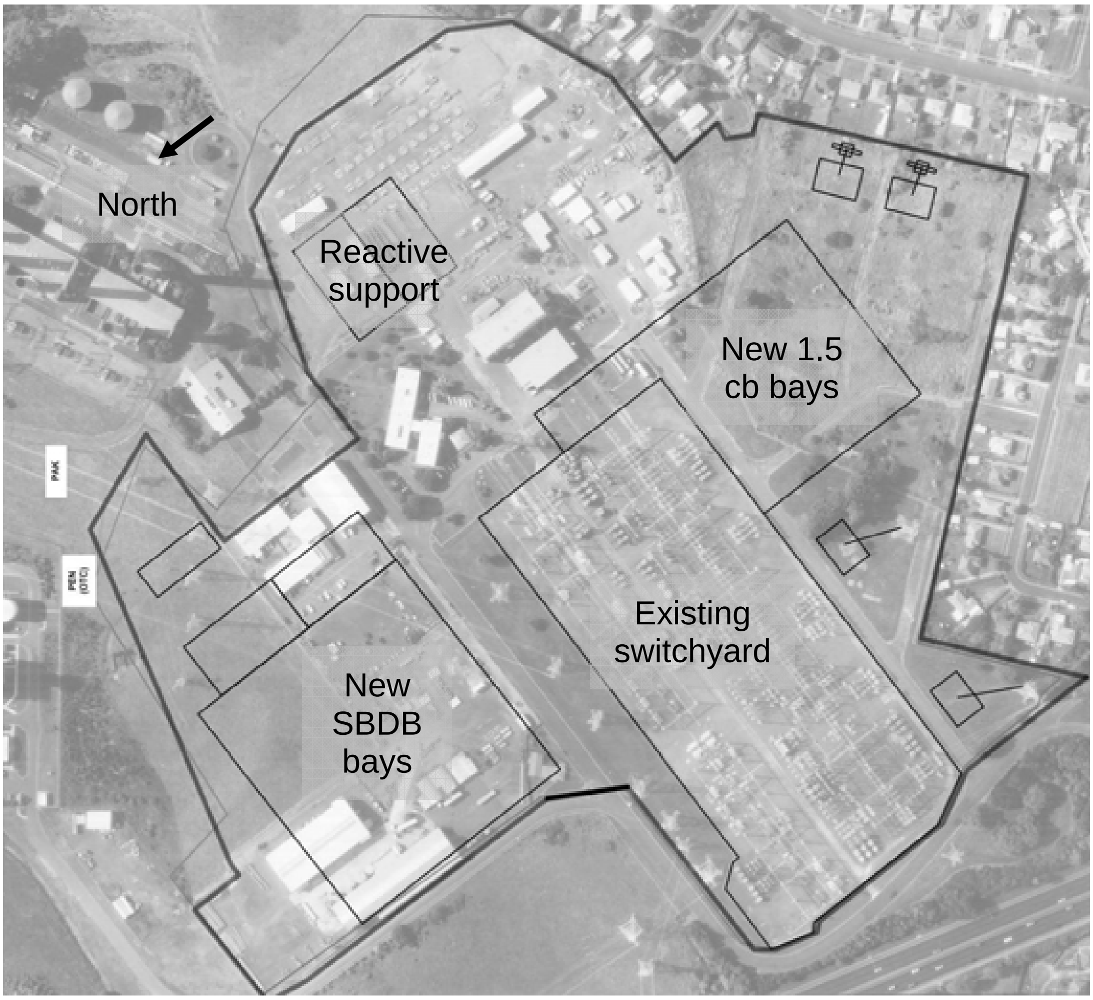

Figure 7-1: Long term development of Otahuhu substation under the reference case

Under the reference case, the switchyard extension is not commissioned until 2013, and accordingly there are limited opportunities to diversify existing circuits prior to 2013 to mitigate the consequence of a bus section breaker failure as described in

Section 6.1. Beyond 2013, the new switchyard extension is commissioned and diversification occurs, at which point the common failure mode of a bus section circuit breaker trip is eliminated by design.

7.2 Option 2: Establish a second Air Insulated Switchgear (AIS) Switchyard

This option is similar to the reference case, with the main difference being the staging. In this option, a completely new AIS switchyard is built earlier (2009) than in the reference case (2013), with a corresponding earlier improvement in substation reliability.

Another differentiating feature between the reference case and option 2 is physical diversification. In option 2, the new AIS switchyard is physically separate from the existing switchyard, and feeder circuits are diversified between the switchyards early on in the development program. A separate control room is included for the new switchyard, further improving security at Otahuhu. This effectively splits Otahuhu into two geographically separate substations, linked by tie lines (cables).

Option 2 involves the following stages.

Works required immediately (2009):

- build a new, 1.5 circuit breaker switchyard to the north of the existing switchyard;
- remove all crossovers of the existing switchyard and cable relevant feeder entry and exit points. Crossovers are removed by installing underground cables from the 'termination' towers of the overhead lines as they enter the substation, to the switchgear equipment itself;
- diversify circuits between the new and existing switchyards by transferring half of the feeders from the existing to the new switchyard. The removal of double-ups in the existing switchyard will also be carried out at this stage; and
- add bus sections to the existing switchyard. This involves adding four new 220 kV bus section circuit breakers to the existing switchyard.

Future developments:

- Extend the new and existing switchyards to accommodate additional circuits and reactive support as required.

A single line diagram of option 2 is provided in Appendix A.

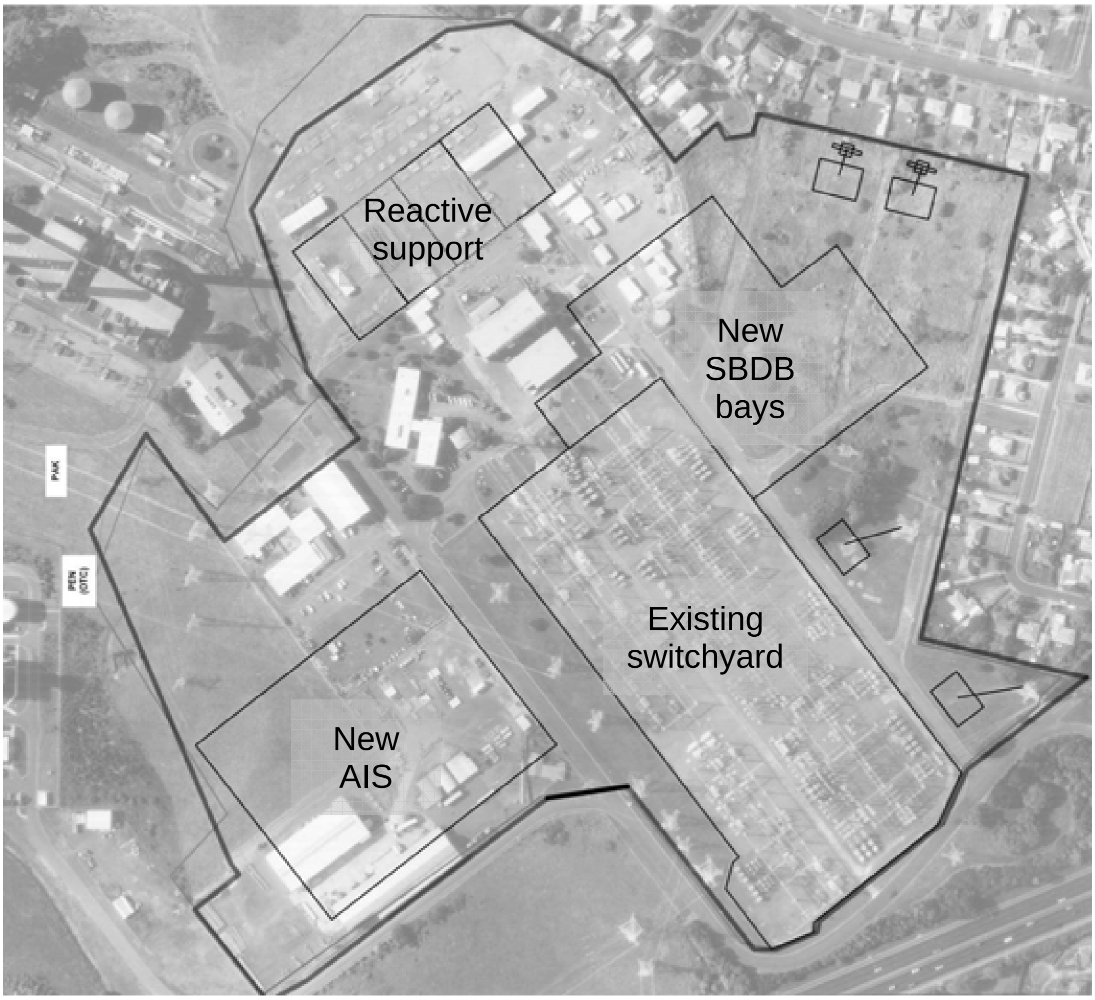

Figure 7-2: Long term development of Otahuhu substation under Option 2

7.3 Option 3: Establish a new Gas Insulated Switchgear (GIS) facility

This option involves building a new GIS/AIS switchyard in 2009, thus enabling the immediate diversification of supplies with the resulting gains in reliability. The new switchyards are located adjacent to the existing switchyard.

The drivers for using GIS for the connection of incoming and outgoing circuits are:

- GIS is three time more reliable than a comparable AIS installation;
- GIS is not exposed to weather or other factors that could affect an open-air installation; and
- Maintenance of GIS equipment is significantly lower than for AIS equipment.

This option includes the following stages.

Works required immediately (2009):

- build a new GIS, 1.5 circuit breaker switchyard, to the north of the existing switchyard. This is for the connection of new circuits only;

- build a SBDB AIS switchyard adjacent to the GIS switchyard. This is for reactive plant and transformers;
- remove all crossovers of the existing switchyard and cable relevant feeder entry and exit points. Crossovers are removed by installing underground cables from the 'termination' towers of the overhead lines as they enter the substation, to the switchgear equipment itself;
- diversify circuits between the new and existing switchyards by transferring half of the feeders from the existing to the new switchyard. The removal of double-ups in the existing switchyard will also be carried out at this stage; and
- add bus sections to the existing switchyard. This involves adding four new 220 kV bus section circuit breakers to the existing switchyard.

The differing switchgear technologies and configurations are selected in order to maximise the reliability of the critical line connections (1.5 circuit breaker GIS) while minimising cost through use of AIS (SBDB configuration) for the less critical reactive plant and transformers. This 'hybrid' use of GIS and AIS technologies represents a prudent approach to achieving high reliability for the critical components of the substation, while at the same time controlling costs for the overall project.

Future developments:

- Extend the new and existing switchyards to accommodate additional reactive support as required.

A single line diagram of option 3 is provided in Appendix A.

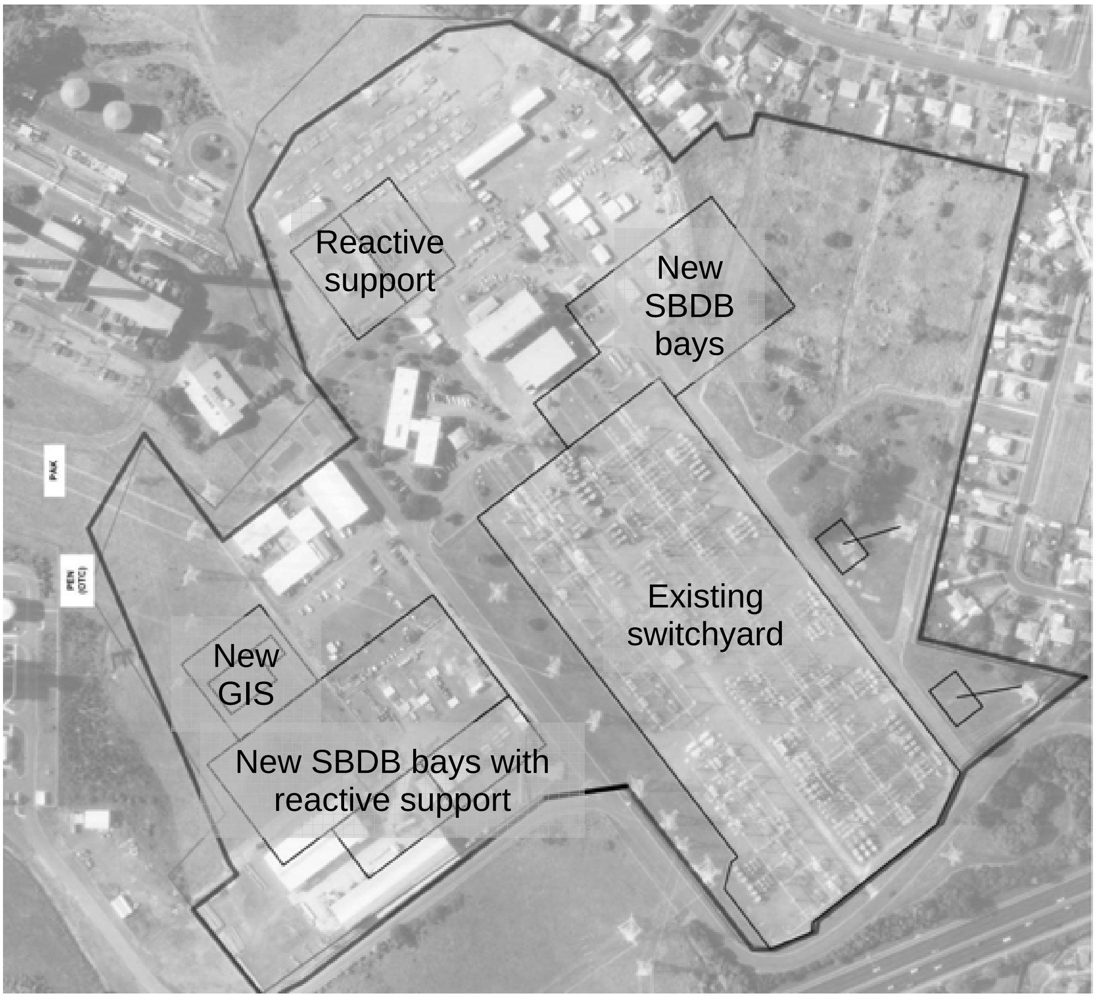

Figure 7-3: Long term development of Otahuhu substation under option 3

7.4 Non-transmission alternatives

Due to the nature and purpose of this proposal, there are no applicable non-transmission alternatives.

8 Comparison of the Options

This section provides a discussion on the merits of each option with respect to the key assessment criteria identified in the 'needs' section as well as a number of other issues, namely:

- compliance with the GRS;
- compliance with the objectives of the GPS;
- geographical diversity;
- electrical diversity;
- options for future development;
- implementation;
- property, consenting and environmental; and
- effect of reliability on business confidence.

8.1 Compliance with the GRS

The existing switchyard fails to comply with the GRS due to a number of rule defined single credible contingency events that would result in the loss of two or more feeders (bus bar faults), which in turn could result in a major disruption to supplies in the area.

Note that the Grid Reliability Standards (GRS) must be applied and interpreted in the context of good electricity industry practice.

The reference case will address the immediate reliability concerns that resulted in the June 12 2006 outage event, but will not address the other needs identified in Section 4 until after the commissioning of the switchyard extensions in 2013. Furthermore, the reference case will not address the underlying issue of having all of Auckland's supplies routed through a single switchyard, leaving an exposure to other low probability events that could affect reliability of all of Auckland's supplies.

8.2 Compliance with objectives of the GPS

Clause 80 of the Government Policy Statement on Electricity Governance states:

"The transmission grid should be adequately resilient against the effects of low probability but high impact events having regard to the load which could be disrupted and the duration of any disruption".

The reference case does not address the impact of low probability, high consequence events that can result in the loss of an entire switchyard as it continues to develop a substation that has a single switchyard with a single control room.

Hindsight shows that if Transpower had diversified the substation as per options 2 or 3 prior to 12 June, then a major outage might have been avoided. There remains, though, the possibility of another type of unforeseen, low probability event causing a similar outage in the future.

Option 2 addresses the reliability concern by providing a new AIS switchyard with an independent control room and diversifying feeders between it and the existing switchyard as soon as possible. Under option 2 however, all equipment will remain outdoors and consequently be subject to external extreme events such as severe weather and malicious attacks that may result in the loss of the entire substation.

Option 3 (GIS) has all the advantages of option 2 regarding diversification between switchyards, but it also provides the highly secure and controlled environment of indoor switchgear. This gives a very high degree of immunity to external extreme events and therefore provides the resilience sought by the GPS.

8.3 Geographical Diversity

Geographical diversity refers to the physical separation of supply infrastructure to avoid local phenomena impacting on key assets or installations. Such phenomena could include major equipment failure (beyond that catered for in N-1 planning) localised weather events, civil unrest, localised problems such as gas leaks or more significant events such as earthquakes. Geographic diversity has three basic forms: switchyard, locational and corridor diversity, as illustrated in Figure 8-1 below:

Greater resiliance

Level of diversity

	Cause of concern	Example of event resilient to	Example of transmission solution for South Auckland
Switchyard	Single switchyard in a substation	Equipment failure Earthquake or extreme weather event	Second switchyard at Otahuhu Load switching capability
Substation	All grid plant in a local area, say 2 by 2 km square	Civil unrest Earthquake or extreme weather event	Second substation as expanded Pakuranga New line or diversion of existing line
Line	A double-circuit tower line (note N-1 dispatch covers for failure of a single circuit line)	Wilful damage Tower collapse Earthquake or extreme weather event	Eastern line from Southern Auckland to Pakuranga
Corridor	Parallel lines within 2 km of each other	Earthquake or extreme weather event	Above plus alternative line to WKM-OTA A, B and C

Figure 8-1: Geographical diversity

Options 2 and 3 will improve the geographical diversity of supply into and out of Otahuhu substation by constructing a new 220 kV switchyard adjacent to, but physically separate from the existing 220 kV AIS switchyard.

The reference case does not achieve this as it retains and extends the existing switchyard. Option 2 (AIS) achieves this, however there are a number of drawbacks when it is compared to option 3 (GIS). These include:

- Limited separation. A new AIS switchyard would be large and would therefore need to be located relatively close to the existing AIS switchyard in order to fit on the existing site. This reduces the benefits of a new switchyard with respect to localised events than can effect both switchyards. NB: the separation provided under option 3 is in the order of 150m, and for option 2, 30m.
- Vulnerability to the elements and localised external events. A new AIS switchyard will be vulnerable to the same type of events that can affect the existing switchyard. Installing a new GIS switchyard will provide a high level of immunity to these events.

Site wide, high impact, low probability events (such as the effects of severe weather) that result in the tripping of a switchyard, are difficult to quantify, and their impact has therefore not been included in the strict economic analysis of the Grid Investment Test.

If an assumption is made that a site wide event, affecting all exposed bus bars and switchgear at Otahuhu occurs once every 100 years, and that the economic cost to local business is similar to that of 12 June (i.e. approximately $100 million), then an annualised cost of $1 million can be added to option 2 as it relies solely on outdoor switchgear. Option 3 however includes an indoor GIS switchyard which is largely immune to severe weather events, and therefore does not attract this penalty.

GIS is inherently more reliable than AIS due to its installation in a controlled environment. This isolates the switchgear from external events as described above, as well as providing stable and controlled surroundings for the current carrying components and connections, for example disconnector switches. Statistics show that GIS switchgear is in the order of three times more reliable than AIS switchgear of the same voltage[3].

8.4 Electrical diversity

Options 2 and 3 improve electrical diversity at Otahuhu by redistributing the major incoming and outgoing 220 kV transmission circuits between the new and existing switchyards. The following lines will each have one of their circuits re-routed to terminate in the new switchyard:

- Huntly – Otahuhu A (incoming)
- Otahuhu – Whakamaru C (incoming)
- Henderson – Otahuhu A line (outgoing)
- Otahuhu – Penrose C line (outgoing)

Together, these circuits represent about half of the total transmission capacity presently routed through the existing Otahuhu substation.

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[3] CIGRE working group 23.02, Survey on HV GIS service experience, Feb 2000

The reference case also achieves some degree of electrical diversity through the addition of a new switchyard extension, however the extension will not be commissioned until 2013, hence the exposure to the risk of unserved energy under the reference case is considerably greater than for options 2 or 3. Furthermore, the reference case retains a single control room which is a single point of failure.

8.5 Options for future development

Transpower ultimately will need to replace or fully refurbish the existing AIS switchyard at Otahuhu. Under the reference case and option 2, there would be insufficient space at Otahuhu to achieve this through the building of a second new switchyard, and alternatives would therefore have to be considered. The alternatives include the following:

- Acquiring additional property to accommodate a second new switchyard. The amount of land required for a second switchyard would be dictated by the technology utilised. It is assumed this would be GIS, due to its small footprint (i.e. less land required). The estimated cost of land for a new switchyard is approximately $7.7M based on a minimum 170m*140m plus a 10m perimeter for cable entries / trenches. Even if land could be acquired adjacent to the potential location of new switchyard, it is likely that the offset location will require longer cable runs and have more property related costs for diverting and cabling the entries of existing lines This alternative would:
    - raise the cost of this future project considerably as current land prices in the area are in the order of $300 per square metre[4];
    - require designation of the newly acquired land; and
    - depending on where the land is acquired, mean re-direction of existing overhead lines and/or further cabling to connect feeders to the new substation.
- Replacing the existing switchyard. This alternative is subject to a constructability review. The risks associated with carrying out this work in a live switchyard would have to be assessed before it is proposed as a viable alternative. This alternative would involve:
    - rearranging connections to the existing switchyard so that one entire bus section could be removed form service at a time (e.g. staged replacement of the existing switchgear); and
    - replacing the existing SBDB switchgear with 1.5 circuit breaker switchgear.

Option 3 alone offers the opportunity to build a second new switchyard on the existing site, thereby avoiding the need to attempt to rebuild the existing switchyard, to purchase additional land. Figure 8-2 shows how a second GIS switchyard would be accommodated on the existing site under option 3 in the future. As shown in the figure, the new GIS switchyard would be located next to the SBDB bays which would be extended to accommodate plant moved from the existing switchyard as it is decommissioned.

[4] Based on a recent sale of land adjacent to Otahuhu Substation at $290/m2.

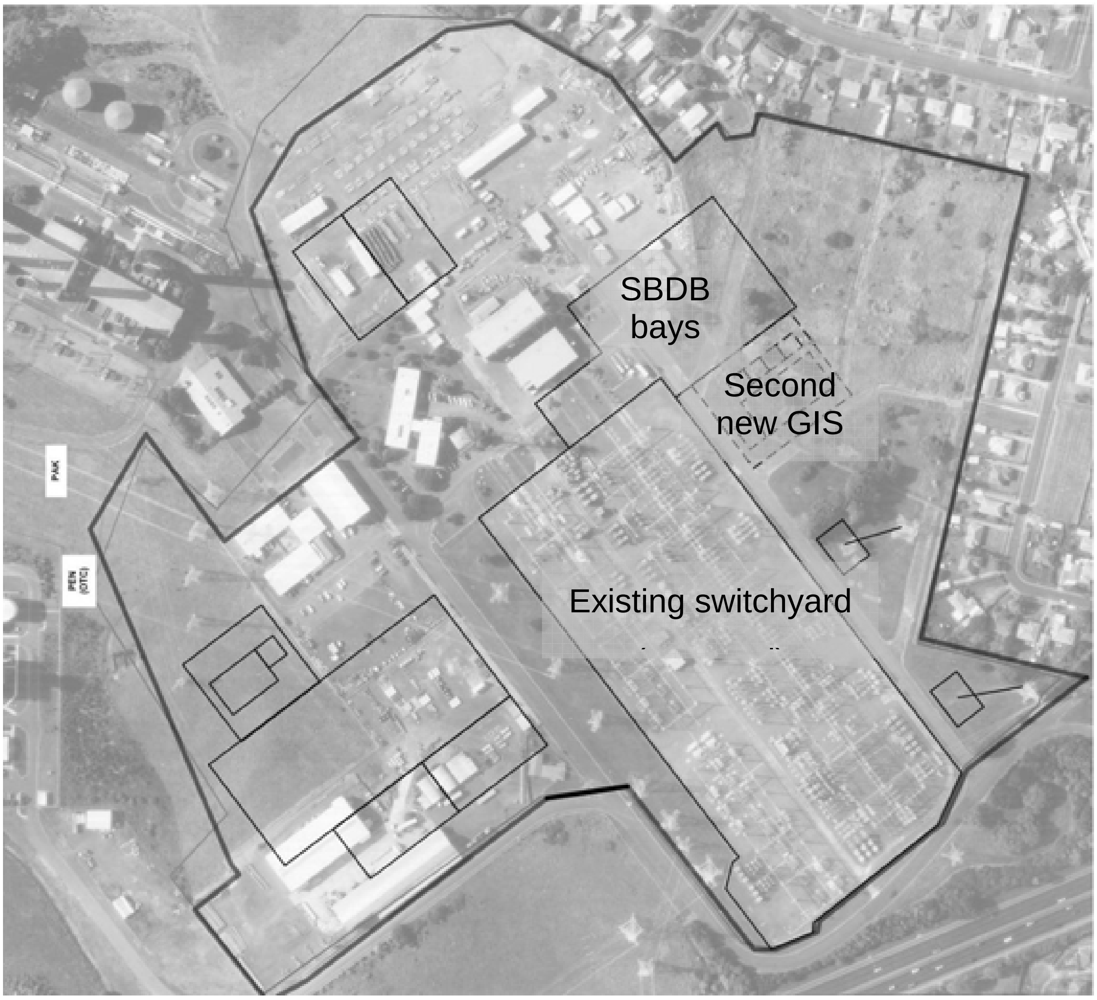

Figure 8-2: Future development of Otahuhu under option 3

8.6 Implementation issues

All three options include the addition of new bus section circuit breakers in the existing switchyard. The installation of these breakers will be carried out in a live switchyard and hence this work will require careful planning from both safety and risk of contingency perspectives. This work is necessary to improve the security of the existing switchyard, but it is Transpower's preference to minimise constriction works in live switchyards.

The reference case involves further work in the existing switchyard to allow for the extension of the existing bus. Options 2 and 3 involve considerably less work in the existing switchyard because they allow for the construction of a new switchyard adjacent to, but separate from the existing switchyard.

The implementation risks associated with options 2 and 3 are therefore less than for the reference case due to less work being required in a live switchyard. This means a lower risk to personnel and a lower risk of a contingency event occurring during construction that could interrupt supply through Otahuhu substation.

The risk of an interruption at Otahuhu during construction is of particular importance to Contact Energy who own and operate the CCGT generator adjacent to the substation. Contact have stressed that the risk of an incident during construction works is of great concern to them with respect to the potential impact that such an event would have on their ability to generate. Transpower is continuing discussions with Contact on this issue but it is apparent that it is preferable to minimise accidental tripping risk by minimising work in live switchyards. This favours options 2 and 3.

8.7 Property requirements

Transpower owns the land at Otahuhu substation, however some new property rights will need to be secured, and some existing property rights re-negotiated, to allow for construction of the new switchyard and associated re-arrangement of existing infrastructure at Otahuhu substation.

Additional land, currently in the ownership of Manukau City Council is required for re-alignment and under-grounding / termination of the Henderson-Otahuhu A line into Otahuhu substation; and cabling one circuit of the Otahuhu-Penrose C line into the existing Otahuhu switchyard.

The new switchyard and associated infrastructure will encroach on land owned by Transpower but subject to an existing lease. Some re-negotiation of the lease is expected.

Subject to discussions with Contact Energy Limited, transmission easements may be required for minor realignments of existing lines into Otahuhu substation, in particular, the Otahuhu A tie-line 2, and the Otahuhu-Penrose C line.

These requirements are common to the reference case and the two options.

8.8 Environmental Impact and Consenting

The following analysis presents a consideration of the Otahuhu substation security upgrade options from an environmental and social perspective in accordance with the statutory tests of the Resource Management Act 1991 (RMA).

The Otahuhu substation site is not presently designated in the Manukau City Council (MCC) District Plan, hence any site development which does not comply with MCC District Plan requirements, and cannot demonstrate existing use rights, must obtain either a resource consent, or designation. Furthermore, the activities on the site significantly exceed District Plan requirements for audible noise. This increases the onus on Transpower to mitigate noise for future upgrade activities, as under section 16 of the RMA, any new activities will be required to demonstrate that they are the best practicable option to avoid unreasonable noise.

It should be noted that although the views presented below were formed after specific and focused discussions with officers of the MCC regarding planned activities at Otahuhu substation, the ultimate interpretation of the various attributes when determining whether or not the consent/designation will be granted is totally at the discretion of MCC and will be subject to final design detail submitted when NOR or resource consents are lodged.

Consenting Risks

Of the three options that were discussed with the MCC, Option 3 (GIS) provides the greatest opportunity for environmental mitigation, and the least risk to overall consenting by 2009. This assumes that a short term consenting strategy is undertaken to enable year 2009 activities and that longer term the site is designated. Under this approach a short term consent is processed on a non-notified basis (recognising the scale of effects and fact that activities comply with the permitted baseline), with the lead time for subsequent activities accommodating notification and further information requirements for the latter designation.

The reference case is less preferable than Option 3 on account of it providing a greater scale of visual effect, and audible noise. The location of AIS equipment to the west in 2009 provides some mitigation from visual effects, and opportunity to mitigate audible noise, however, when considered in conjunction these activities pose increased risks to Transpower's ability to comply with the permitted baseline. This increases the likelihood that Council will seek written approval from adjacent landowners, or process the application for year 2009 activities on a notified (limited) basis. As a consequence, the consent process will incur greater requirement for environmental mitigation (e.g. landscaping, acoustic mitigation), notification, evidence preparation and hearings and thereby increased timeframes from those associated with consenting Option 3. The purchase of dwellings (or installation of acoustic mitigation such as double glazing at such properties) within close proximity to the substation would ensure effects are adequately mitigated. However this is a costly exercise (current estimates for purchase of the potentially affected properties is $13 million) , and may not be required if Transpower provided a firm undertaking to designate the site longer term and in so doing, reduce audible noise levels over time.

Option 2 (AIS) is least preferred of all options on account of the location of visually prominent and noisy equipment close to residential boundaries. This scenario provides limited opportunities to mitigate effects, with the exception of purchasing (or installing additional acoustic mitigation to) existing dwellings adjacent to the substation. Taking into account the limited opportunities to mitigate noise, there is a high risk that the purchase of dwellings or installation of acoustic mitigation at affected properties would be required as a condition of any consent prior to the first equipment being installed in 2009. Furthermore, it is highly likely that any consent application would be notified – irrespective of Transpower's decision to purchase property. This will significantly reduce the feasibility of installing the first equipment in 2009. In this scenario, there is unlikely to be an opportunity to lodge a short term consent, as the scale of effects requires that any consenting strategy mitigate a more comprehensive scale of effects than either option 3 or the reference case and in so doing address issues best addressed in a site designation.

Quantifying the effects

The above consenting risk is quantified in the economic analysis through a 12 month time penalty for the reference case and option 2 with a corresponding increase in unserved energy, when compared to option 3. This represents the time expected to process a notified consent application through the MCC for the planned activities at Otahuhu substation.

In addition to the costs of unserved energy it is likely that both the reference case and option 2 would require noise mitigation for plant near the residential boundary. This would involve (as a minimum) the installation of specially designed low noise equipment (e.g. vacuum switches) for the switching of capacitor banks at $180,000 per capacitor bank. This adds to the cost of option 1 and 2 which both have capacitor banks located adjacent to residential boundaries.

8.9 Effects of reliability on business confidence

Low probability, high consequence events that result in the tripping of multiple feeders in a switchyard, can and do occur. This is evidenced from the events of June 12 2006 where a single unforeseen event resulted in the loss of most of the switchyard at Otahuhu. These events are difficult to define or predict, but local and international experience proves that they will occur regardless of best endeavours to ensure that they do not. Where rare events such as these have a low impact, they can be tolerated. However at critical sites such as Otahuhu substation where they have very high impact, they cannot.

Because all significant supply currently connects through Otahuhu, a major substation fault has the potential to disrupt all or a significant portion of Auckland load, currently peaking at around 2200 MW. Until additional supply projects to Auckland are implemented, the loading of the transmission system is expected to be high while the risk of multiple contingencies increases all the time.

The cost of a widespread supply interruption – such as the one that occurred on 12 June 2006 – is difficult to assess with precision but is thought to be in the order of $50-$100M. In addition to these costs, there is a potential loss of confidence for investors that could result in lost investments. Given that two major supply events have occurred in Auckland in the last decade, a further problem would potentially have a significant effect on confidence in supply reliability.

Furthermore, the transmission capability into Auckland is limited by reactive support capability and a multiple contingency at a time of high loading would have the potential to cause a loss of voltage control and possibly collapse. Such a voltage collapse incident could affect a wider area than just Auckland.

Transpower therefore considers the need for this project to be urgent in order to reduce the probability of further low probability – high consequence events disrupting power supply to the Auckland area.

8.10 Summary - Comparison of options

Table 8-1 shows a comparison of these options:

	Options considered		
Comparison criterion	**The reference case: Develop existing substation**	**Option 2: Establish new AIS switchyard**	**Option 3: Establish new GIS facility**
GRS compliance	Yes	Yes	Yes
Electrical diversity	No	Yes	Yes
Implementation risk	High	Low	Low
GPS compliance (s80)	No	Partly	Yes
Geographical diversity	No	Limited	Yes
Effect on business confidence	No change	Improves	Best
Consenting risk	High	Highest	Low
Options for the future	No	No	Yes

Table 8-1: Comparison of Otahuhu substation reliability improvement options

9 Transpower's Proposal

9.1 Approval Sought

Transpower seeks approval from the Commission to recover the actual costs incurred in delivering the project, through the transmission pricing methodology, following commissioning of the project. Costs are to include the accrued interest charged on works under construction.

The following works make up Transpower's Otahuhu substation diversity proposal:

- Remove all over-crossings of the existing substation at Otahuhu
- Install two bus section circuit breakers in the existing 220 kV switchyard
- Procure, construct, commission and operate a new 220 kV GIS switchyard and a new AIS switchyard at Otahuhu, connected and adjacent to but geographically separated from the existing switchyard
- Transfer approximately half of the circuits from the existing switchyard to the new switchyard
- Obtaining designations, and resource consents necessary for the above
- Plan for commissioning of the new switchyards by 2009.

9.2 Description of Works

Transpower proposes that Option 3 (GIS) be adopted for Otahuhu substation. This option is as described in Section 7.3 and is detailed below.

- construct a new 220 kV Gas Insulated Switchgear (GIS) facility adjacent to but physically separate from the existing 220 kV switchyard. This switchyard will be for the connection of incoming and outgoing circuits;
- construct a new 220 kV air insulated switchgear facility adjacent to the new GIS building in single breaker double bus configuration. This switchyard will be for the connection of reactive plant and transformers;
- connect the existing switchyard to the new GIS switchyard by two cable tie lines;
- rearrange the existing 220 kV Henderson and Penrose outgoing lines and the 220 kV Huntly and Whakamaru incoming lines so that one circuit from each line will be connected to the new 220 kV GIS facility. Rearrangement of these key incoming and outgoing circuits will result in a split of circuits between the existing switchyard and new switchgear so that the loss of either facility will not result in a total loss of transmission capacity into Auckland and Northland;
- construct a new control room for the two new switchyards. This will be geographically and electrically independent from the existing control room

- remove and cable existing 220 kV crossovers of the 110 kV bus; and
- install two bus section circuit breakers in the existing switchyard in order to improve it's reliability;

The new facility will be designed to allow for expansion over time for additional incoming and outgoing circuits (GIS) and transformers and voltage support equipment (AIS) as they are required.

The new switchgear facilities will be built to current industry design and reliability standards. They will also be specified to accommodate Transpower's longer term strategic goals for the site.

The existing 220 kV switchyard will be retained in its current configuration, albeit with a reduced density of connections owing to the sharing of circuits and connections with the new AIS switchyard.

The existing 110 kV switchgear will be retained following the construction of the new GIS facility and the reallocation of circuits.

9.3 Proposal costs

Transpower is seeking Electricity Commission approval for costs incurred by Transpower in the implementation of the proposal. The estimated capital cost for the amended proposal is $83m in $2006, including contingencies ($75m excluding contingencies).

Category	Estimated Cost $m (2006)	Estimated Cost including Contingencies $m (2006)
Design	1	1
Enabling Works	7	8
Substation Works – AIS	7	8
Substation Works - GIS	30	33
Transmission Lines/Cabling	24	27
Project Management	6	6
Total	**75**	**83**

Table 9-1: Proposals Costs

Projects included in these cost estimates are those described in Section 7.3, under the subheading 'Works required immediately'.

To determine an amount for its approval request Transpower has estimated the mid-point and 90% limit of project costs on commissioning of the proposal.

The mean project cost estimate in June 2009 dollars is $94 million. The 90% limit of project costs has been estimated at $99 million. The chart below shows the distribution of project costs.

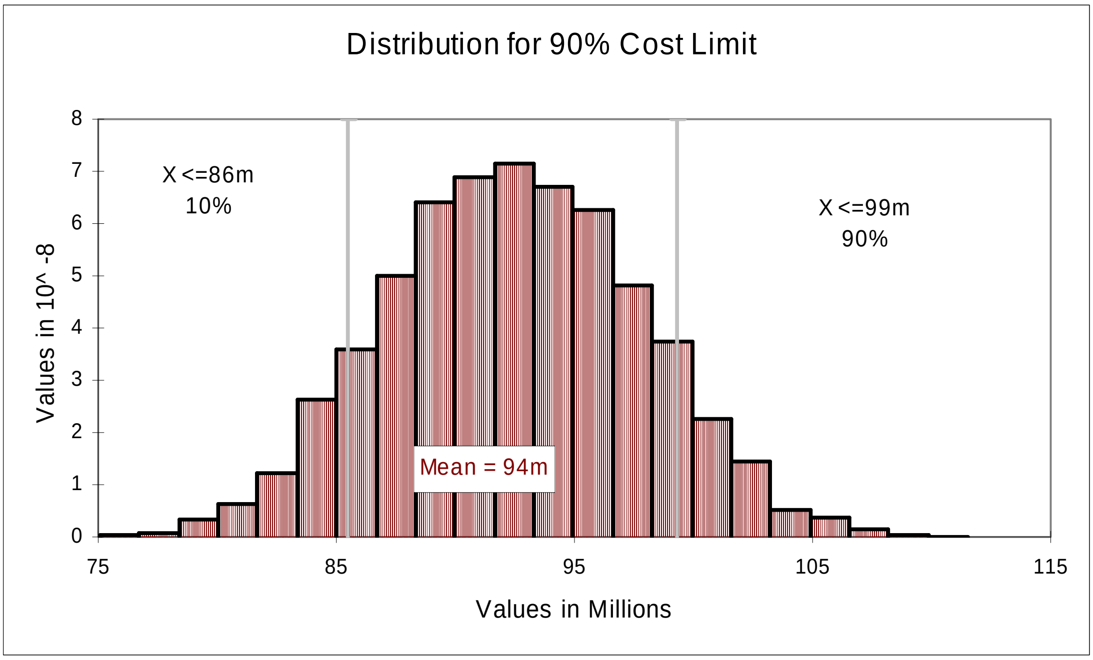

Figure 9-1: Distribution of Proposal costs

Table 9-2 shows the amended proposal costs without simulation. The total cost is expected to equal $94m, in $2009, which includes an $8m inflation adjustment.

Category	Cost $m (2006)	Contingencies	Exchange Rate Variation	Interest During Construction	Fully Adjusted Cost $m (2006)	Inflation	Fully Adjusted Cost $m (2011)
Design	1	0	0	0	1	0	1
Enabling Works	7	1	0	1	9	1	10
Substation Works AIS	7	1	0	0	9	1	10
Substation Works GIS	30	3	0	1	34	3	37
Transmission Lines/Cabling	24	2	0	1	27	2	29
Project Management	6	0	0	0	6	1	7
Total	75	8	0	3	86	8	94

Table 9-2: Proposal costs without simulation

Including simulation, a 90% upper limit on project cost is expected to equal $99m, in $2009, which includes a $10m inflation adjustment.

Category	Cost $m (2006)	Contingencies	Exchange Rate Variation	Interest During Construction	90% Cost Limit $m (2006)	Inflation	90% Cost Limit $m (2011)
Design	1	0	0	0	1	0	1
Enabling Works	7	1	0	1	9	1	10
Substation Works AIS	7	1	0	0	8	1	9
Substation Works GIS	30	3	2	2	37	4	41
Transmission Lines/Cabling	24	2	1	1	28	3	31
Project Management	6	0	0	0	6	1	7
Total	75	8	3	4	89	10	99

Table 9-3: Proposal costs with simulation

Method for Estimating 90% Cost Limit

The Monte Carlo technique was used to estimate the mid-point and 90% limit on project costs. The cost of the proposal is simulated a large number of times, and the frequency of simulation results is used to establish costs for a given level of likelihood.

Costs for projects and other elements of the proposal are broken down into components including:

- Costs denominated in New Zealand dollars
- Costs denominated in other currencies
- Property costs

The projects occur on a staggered basis and costs have been streamed over various dates to reflect project timing, and to allow calculation of interest during construction[5].

The model takes into account the following variables:

- Exchange rates

[5] For property purchases it has been assumed that if the proposal is approved the cost of land and easements can be included in Transpower's revenue base once route acquisition has been completed. Interest during construction costs will be higher if these costs must be incurred until completion of the transmission line, and lower if Transpower can recover these costs from the time of the land acquisition.

- Inflation
- Real interest rates
- Price accuracy
- Scope contingencies

Cost estimates also include an allowance for interest during construction.

Assumptions for Key Variables

Exchange Rates

Point estimates of capital cost were based on 10 year average exchange rates. These were subsequently adjusted to smoothed spot rates using the average exchange rate 20 business days either side of 30 June 2006. For the simulation runs, exchange rates have been sampled from daily exchange rates over the period 1 July 1996 to 30 June 2006. This approach ensures that the simulated exchange rates and cross-rates have a similar mean and variance to historical rates. Over a large number of simulations the exchange rate will be close to the 10-year average rate.

Inflation

Inflation is modelled by drawing from a uniform distribution in a range from 2% to 4%.

Real Interest Rates

The real interest rate is modelled by drawing from a uniform distribution in a range from 6% to 8%. The nominal interest rate is the real interest rate plus the inflation rate.

Price Accuracy

As regulatory approval occurs prior to the issuing of tenders, there is uncertainty over the price of equipment to be installed. This has been modelled by expressing the accuracy of estimates as a triangular distribution, assuming +/-20% accuracy. The point estimate of costs is given as the most likely outcome, and lower and upper bounds are expressed as percentages of the midpoint.

Scope Contingency

Scope contingencies have been included to cover two distinct categories of costs:

- costs for works which are planned, but which have not been included in the cost estimates except through a general allowance; and
- costs for works not anticipated at the time costs were estimated.

For the purpose of simulation modelling scope contingencies have been treated as a fixed percentage, i.e. scope contingencies as a percent of costs do not vary between simulations. They may vary in dollar terms because of changes in other input variables. This is consistent with the definition of expected costs used in the economic analysis.

9.4 Proposal is a reliability investment

According to Part A of the Electricity Governance Rules, a reliability investment is

> *"investments by Transpower in the grid, or alternative arrangements by Transpower, the primary effect of which, or would be, to reduce expected unserved energy"*

The primary driver for the Otahuhu substation upgrade is to reduce expected unserved energy by diversifying the sources of supply into the Auckland region. The immediate driver is that the existing substation does not meet the requirements of Clause 4.2 of the GRS.

The need for new investment to reduce expected unserved energy in the upper North Island is demonstrated in the Economics Analysis report (Attachment B). The analysis concludes that there is a risk of electricity demand not being supplied in Auckland and Northland as the direct result of quantified low probability, high consequence events in the existing switchyard, and that hence new investment is required to maintain security of supply into the region.

The Proposal outlined in this application is designed to reduce the expected unserved energy identified in the needs analysis referred to above. Therefore both limbs of the grid reliability standards are relevant, being the probabilistic limb (Clause 4.1 of Schedule F3) and the deterministic limb (Clause 4.2 of Schedule F3). That the Proposal meets these limbs is demonstrated in section 10.

10 Proposal meets the requirements of the rules

Rule 13.4.1 sets out three criteria that a proposed reliability investment must meet in order to gain approval from the Commission. The following subsections set out these criteria, and discuss why the Otahuhu substation upgrade proposal meets these criteria.

10.1 Reflects GEIP in meeting the GRS

The first criterion for approval under Rule 13.4.1 requires that the proposed reliability investment:

> *13.4.1.1 "reflects good electricity industry practice in meeting the grid reliability standards"*

The grid reliability standards (GRS) are contained in Schedule F3, which states that:

> *4 "For the purposes of clause 3, the grid satisfies the grid reliability standards if:*
>
> *4.1 the power system is reasonably expected to achieve a level of reliability at or above the level that would be achieved if all economic reliability investments were to be implemented; and*
>
> *4.2 with all assets that are reasonably expected to be in service, the power system would remain in a satisfactory state during and following any single credible contingency event occurring on the core grid"*

The Otahuhu substation is part of the Core Grid, as set out in Schedule F3A of the EGRs. In addition to this, as explained in Section 8.3, the proposal is a reliability investment. Therefore both limbs of the grid reliability standards are applicable.

The primary driver for the upgrade of the Otahuhu Substation is due to the fact that Clause 4.2 of Schedule F3, or the deterministic limb of the GRS, is presently not satisfied for the single credible contingency event of a bus fault (refer to Section 4.1 of this report). A minimum amount of work is therefore required to meet the "safety net" set out in the GRS. It should be noted that this is a minimum requirement on the Core Grid, and that Clause 4.1 of Schedule F3 may require a higher standard to be met in order to fulfil the GRS. A closer examination of the expected unserved energy at Otahuhu showed that this was the case. As the economic/probabilistic analysis shows in Attachment B, the level of expected unserved energy at Otahuhu revealed a requirement to invest in the grid to achieve a standard higher than that set out in the deterministic limb of the GRS.

Whether the Proposal meets the GRS as set out in Clause 4.1 of Schedule F3, is synonymous with whether the Proposal satisfies the Grid Investment Test. That the proposal satisfies the Grid Investment Test is demonstrated in Attachment B, and summarised in Section 10.3 below.

10.2 Complies with the rules process

Rule 12.2

Rule 12.2 states that either

- Transpower must submit a Grid Upgrade Plan to the Board within 3 months of receiving a written request from the Board, or such other date as the Board agrees; or
- may submit a Grid Upgrade Plan for Board consideration at any other time.

Transpower has not received a written request for this GUP, but is submitting this document in accordance with the second part of Rule 12.2.

Rule 12.3

Rule 12.3 requires a GUP to include:

12.3.1: a comprehensive plan for asset management and operation of the grid;

12.3.2: information on investment contracts;

12.3.3: the proposed reliability and / or economic investments, with supporting information; and

12.3.4: such other information as prescribed by the Board

As set out in Section 2, this GUP refers to the Comprehensive Plan, and the list of investment contracts, that were set out in Volume I of the first GUP, submitted on 30 September 2005.

The proposed reliability investment is set out in Section 9 above.

Rule 13.2

Rule 13.2 requires the Commission Board and Transpower to agree a timetable for consultation and approval of the reliability investment. In the absence of agreement, the Board may stipulate such a timetable. The Board must consult with Transpower on the process and participants to the consultation.

Rule 13.3.3

Under Rule 13.3.3, the Commission may:

- direct Transpower to undertake further investigations into the proposal;
- ask questions of Transpower or require further information;
- ask Transpower to evaluate alternative reliability investments; and
- where Transpower possesses relevant expertise, ask Transpower to evaluate transmission alternatives.

Transpower undertakes to fulfil any requests the Commission may have in accordance with the above requirements.

10.3 Satisfies the Grid Investment Test

Rule 4 of Schedule F4 states:

4 A proposed investment satisfies the Grid Investment Test if the Board is reasonably satisfied that:

4.1 for a proposed investment that is necessary to meet the reliability standard set out in clause 4.2 of the grid reliability standards:

4.1.1 the proposed investment maximises the expected net market benefit or minimises the expected net market cost compared with a number of alternative projects; and

4.1.2 if sensitivity analysis is conducted, a conclusion that a proposed investment satisfies clause 4.1.1 is sufficiently robust having regard to the results of that sensitivity analysis; or

4.2 for any other proposed investment:

4.2.1 the proposed investment maximises the expected net market benefit compared with a number of alternative projects;

4.2.2 the expected net market benefit of the proposed investment is greater than zero; and

4.2.3 if sensitivity analysis is conducted, a conclusion that a proposed investment satisfies clauses 4.2.1 and 4.2.2 is sufficiently robust having regard to the results of that sensitivity analysis.

As discussed in Section 10.1 above, the primary driver for investment in the Otahuhu substation is to ensure the grid at Otahuhu meets Clause 4.2 of Schedule F3, or the deterministic limb of the GRS. However the level of expected unserved energy at Otahuhu warrants investment beyond this safety net. As such, Clause 4.1 of Schedule F3 becomes the standard that must be met, and Clause 4.2 of Schedule F4 becomes the relevant test with regard to the GIT. In light of Clause 4.2 of Schedule F4, this means that in order to satisfy the GIT the Proposal must:

- maximise the expected net market benefit compared with a number of alternative projects;
- have expected net market benefit greater than zero; and
- meet the above two conditions when subject to sensitivity analysis.

The analysis set out in this section and in Attachment B shows that the proposal meets these three requirements of Clause 4.2 of Schedule F4, being the relevant test within the GIT.

Table 10-1 presents the summarised rankings of the proposal and alternatives as a result of the application of the Grid Investment Test.

The results in Table 10-1 (provided in 2006 dollars) show that the proposed investment (Option 2) passes Clause 4.1.1 of the GIT by having the lowest expected net market cost of the three alternatives.

	Extend Existing Switchyard	**2nd AIS Switchyard**	**GIS Switchyard**
	2006 dollars (millions)		
Capital cost (A)	75.8	80.0	82.2
Consenting and noise abatement costs (B)	0.0	0.5	0.0
Operations and maintenance costs (C)	1.9	3.0	2.6
Saving in Expectation of Unserved Energy (D)	10.3	21.5	23.2
Terminal value (E)	2.9	1.7	3.0
Terminal Benefit (F)	4.0	4.0	4.1
Mean NPV cost* **(A+B+C-D-E-F)**	60.5	56.1	54.3
Difference v Reference Case (i.e. is less expensive than the reference case by…)		4.4	6.2 [1]

Note 1:- Benefits attributable to option 3 (GIS) that are not included in the economic investment test, but none the less are quantifiable include:

- Property costs. For the reference case and option 2 the cost of new land required to replace the existing switchyard in the future is estimated at $7.7 million (ref section.8.5)
- Immunity to site wide, high impact, low probability events, for example severe weather that affects all AIS switchgear and bus work. The annualised NPV of this is estimated at $1 million (ref section.8.3)

Taking these benefits in to account will increase the economic advantage of the GIS option over the AIS option from $1.8 million to $10.5 million.

Table 10-1: Ranking of alternatives

Table 10-2 presents a summary of the sensitivity studies used to confirm the rankings of the proposal and the alternatives for a variety of changes to key parameters.

-$2006 million-	Extend Existing Switchyard	2nd AIS Switchyard	GIS Switchyard	ENMC Diff GIS – E.E.
Base results	**60.5**	**56.1**	**54.3**	**-6.2**
Sensitivity:				
10% POE demand path only	58.7	53.9	52.4	-6.3
90% POE demand path only	61.7	57.5	55.2	-6.4
Capital cost +20%	75.7	72.1	70.8	-4.9
Capital cost -5%	56.7	52.1	50.2	-6.5
Value of unserved energy $10,600/MWh	65.7	66.9	66.0	0.3
Value of unserved energy $31,800/MWh	55.4	45.3	42.7	-12.7
Discount rate of 4%	52.1	45.2	42.8	-9.3
Discount rate of 10%	60.0	57.9	56.4	-3.5
$2009	66.1	61.3	59.4	-6.8
Lines to PAK built 2015	57.2	49.9	48.6	-8.7

Table 10-2: Sensitivity of expected net market cost of proposal and transmission alternatives to various parameter changes

Further details and analysis on the application of the GIT are provided in Attachment B

11 Project Timing

A project of the proposed investment's magnitude would normally be expected to take between two and two and a half years from approval to final commissioning.

Transpower has identified that the earliest date the proposed investment can be in place is early to mid 2009, provided investigation and planning commences now[6].

Any delay in project commencement will result in delay through the project.

[6] This timeline assumes there will be no appeals to the courts.

12 The proposal is consistent with wider policy objectives

Transpower notes the application is being submitted within the context of a wider regulatory framework. As such, points of reference within that wider framework that can reasonably be assumed to be relevant are:

- the purpose of Section III of Part F of the Electricity Governance Rules;
- the Government Policy Statement on Electricity Governance (GPS); and
- the Commission's objectives under the Electricity Act 1992.

12.1 The purpose of Section III of Part F

Transpower believes that the following factors are relevant to the Commission's consideration of the Otahuhu Substation Diversity Project proposal:

	Rule 2: Purpose of Section III of Part F	Would approval of the proposal contribute to this purpose?
2.1	"facilitate Transpower's ability to develop and implement long term plans (including timely securing of land access and resource consents) for investment in the grid"	Yes The proposal is a component of Transpower's long term plans.
2.2	"assist participants to identify and evaluate investments in transmission alternatives"	Yes, albeit that any proposal following the Part F process will achieve this.
2.3	"facilitate efficient investment in generation"	Yes The proposal will provide assurance of releasable capacity into the Upper North Island from the Lower North Island and the South Island. This will provide both capacity and confidence to generation investors.
2.4	"facilitate any processes pursuant to Part 4A of the Commerce Act 1986"	Yes, albeit that any proposal following the Part F process will achieve this.
2.5	"enable the cost of approved investments to be recovered through the transmission pricing methodology applied in transmission agreements"	Yes, albeit that any proposal following the Part F process will achieve this.

Table 12-1: Rule 2 – Purpose of Section III of Part F of the EGRs

12.2 The GPS

In October 2006, the Ministry for Economic Development released a new version of the Government Policy Statement on Electricity Governance. The October version highlights the role of the transmission grid in a number of areas, including maintaining consumer and investor confidence. Two new objectives in the GPS which achieve this, and which the Otahuhu Substation Diversity Project in particular meets, are:

- ensuring the grid is adequately resilient against the effect of low probability but high impact events; and
- where practical, ensuring the grid provides adequate supply diversity to larger loads.

Table 12-2 below lists the relevant objectives for the provision of transmission services in the October 2006 GPS, and explains how the Otahuhu Substation Diversity Project helps the Commission to meet these objectives.

GPS objective	Contribution of proposal to meeting the objective
Transmission	
Objectives for the provision of transmission services	
80 The Government's objectives for the provision of transmission services are that:	
• The services are provided in a manner consistent with the Government's policy objectives for electricity and in particular that grid reliability should be maintained at a level required by residential, commercial and industrial users and the Government's economic objectives	The submission from Auckland's distribution company (Vector) with respect to the recent IGE for Otahuhu diversity project illustrates the importance that directly affected parties place on reliability. Transpower's proposal is consistent with achieving a high level of grid reliability for New Zealand's largest city.
• The transmission grid should be adequately resilient against the effects of low probability but high impact events having regard to the load which could be disrupted and the duration of any disruption	Benefit is gained with respect to this type of event under both options 2 and 3 GIS (option 3) provides higher immunity to this type of event than option 2 (AIS) due to the switchgear being enclosed and isolated from external influences.
• Where practical, the transmission grid should provide adequate supply diversity to larger load centres having regard to the load which could otherwise be disrupted and the duration of any disruption	Auckland represents New Zealand's largest area of load and it suffers most from the effects of unscheduled outages such as that of 12 June 2006. This proposal represents a "practical" opportunity to improve the reliability of supply into Auckland.

Table 12-2: The GPS objectives for the provision of transmission services

13 Recommendation

It is recommended, therefore, that the Commission approve the proposal to build a new GIS switchyard at Otahuhu as per option 3, on the grounds that it:

- meets the GRS;
- is consistent with the objectives of the GPS;
- complies with the Rules;
- passes the GIT;
- is consistent with GEIP; and
- provides clear advantages over the alternatives with respect to:
    - long term development plans;
    - geographical diversity; and
    - consenting issues.

Appendix A – Single Line Diagrams

Note:

The nomenclature used for labelling of the options in appendix A differs from that used in the Proposal document as follows:

Proposal label	Appendix label
Reference case	Option 1A
Option 2	Option 2A
Option 3	Option 8

The diagrams in the appendix are indicative only.

Appendix B – Transpower historical data on 220 kV SF6 circuit breaker failure rates

220 kV SF6 CBs - Fault Rates 7/92 to 7/06

		220 kV SF6 CB Number of Faults				220 kV SF6 CB Fault Rates - Faults per 100 per annum			
	Assumed Population	Faults Causing Auto Trippings	Faults Requiring Manual Outage	Faults on Return to Service	Total Faults	Faults Causing Auto Trippings	Faults Requiring Manual Outage	Faults on Closing / Return to Service	Total Fault Rate
1992-93	253	0	16	0	16	0.0	6.3	0.0	6.3
1993-94	253	0	16	0	16	0.0	6.3	0.0	6.3
1994-95	253	0	4	0	4	0.0	1.6	0.0	1.6
1995-96	254	0	23	0	23	0.0	9.1	0.0	9.1
1996-97	257	3	17	1	21	1.2	6.6	0.4	8.2
1997-98	264	1	3	3	7	0.4	1.1	1.1	2.7
1998-99	273	0	5	1	6	0.0	1.8	0.4	2.2
1999-00	284	2	1	0	3	0.7	0.4	0.0	1.1
2000-01	299	1	5	1	7	0.3	1.7	0.3	2.3
2001-02	315	0	4	1	5	0.0	1.3	0.3	1.6
2002-03	335	1	8	1	10	0.3	2.4	0.3	3.0
2003-04	358	3	11	1	15	0.8	3.1	0.3	4.2
2004-05	383	0	3	3	6	0.0	0.8	0.8	1.6
2005-06	410	0	1	1	2	0.0	0.2	0.2	0.5
				Faults per 100 pa		0.3	3.0	0.3	3.6
				Years between faults		376	32	337	27