TRANSPOWER

North Island Grid Upgrade Project

Amended Proposal

Attachment A

Diversity into the Upper North Island

Technical Analysis of Diversity Options for New Capacity into the Upper North Island

October 2006

Contents

1 Introduction

A recent event at Otahuhu Substation (June 12th 2006) that resulted in wide spread loss of supply to the Auckland area has lead to an increase in focus on the benefits of diversity, at all levels of the power system, including major substations such as Otahuhu.

This report analyses the effect on diversity into Auckland and Northland of locating the terminal point of the proposed new Upper North Island line at Pakuranga instead of Otahuhu substation. The results include an assessment of the benefits gained in terms of capacity available into Auckland and Northland, under each option, for various substation contingency scenarios.

The report also considers the benefits diversifying the switchyard at Otahuhu. Transpower have recently lodged an application with the Electricity Commission in August 2005 for approval to build a new switchyard at Otahuhu, to improve diversity and to cater for planned expansion at the substation. Implementation of the project will improve the resilience of Otahuhu substation so that it may withstand a single locational event such as that which occurred on June 12th from disrupting all supplies through Otahuhu.

2 Assumptions

2.1 Configuration and Development Options

Two basic configurations for the new Auckland to Whakamaru transmission line are assumed:

a) New line terminates into Pakuranga
b) New line terminates into Otahuhu

The diversity provided by each of these configurations is assessed with and without a new switchyard at Otahuhu.

Two new 220 kV cable connections are assumed to be installed between Pakuranga and Penrose for the Pakuranga option (a), along with the conversion of the existing 110 kV Otahuhu-Pakuranga line to 220 kV.

Two new 220 kV cable connections are assumed to be installed between Otahuhu and Pakuranga for the Otahuhu option (b), along with the conversion of the existing 110 kV Otahuhu-Pakuranga line to 220 kV.

2.2 Timing

A 'snapshot' of the system configuration as expected in 2013 is used as the basis for the analysis. This assumes that the first stage of the cross Auckland project is completed with one 220 kV cable connection between Penrose and Albany via Hobson Street and Wairau Road substations[1].

[1] Hobson Street and Wairau Road are presently zone substations that will converted to Grid Exit points when the first Penrose to Albany 220 kV cable is installed.

2.3 Circuit capacities

The capacities of all new circuits are assumed to be as follows:

Circuit	Type	Number of circuits	Capacity
Transition station[1] to Pakuranga	cable	2	660 MVA per circuit
Transition station to Otahuhu	cable	2	660 MVA per circuit
Pakuranga to Penrose	cable	2	660 MVA per circuit
Otahuhu to Penrose	cable	2	660 MVA per circuit
Penrose to Albany (via Hobson St and Wairau Rd)	cable	1	630 MVA per circuit

1. This is where the overhead line makes the transition to underground cables.

2.4 Existing System

2013 peak loads, calculated using a medium load growth scenario are used for this analysis. Note that the load figures used in this report are approximate and are for comparative purposes only.

The figure below provides an indication of the magnitude of these loads in 2013.

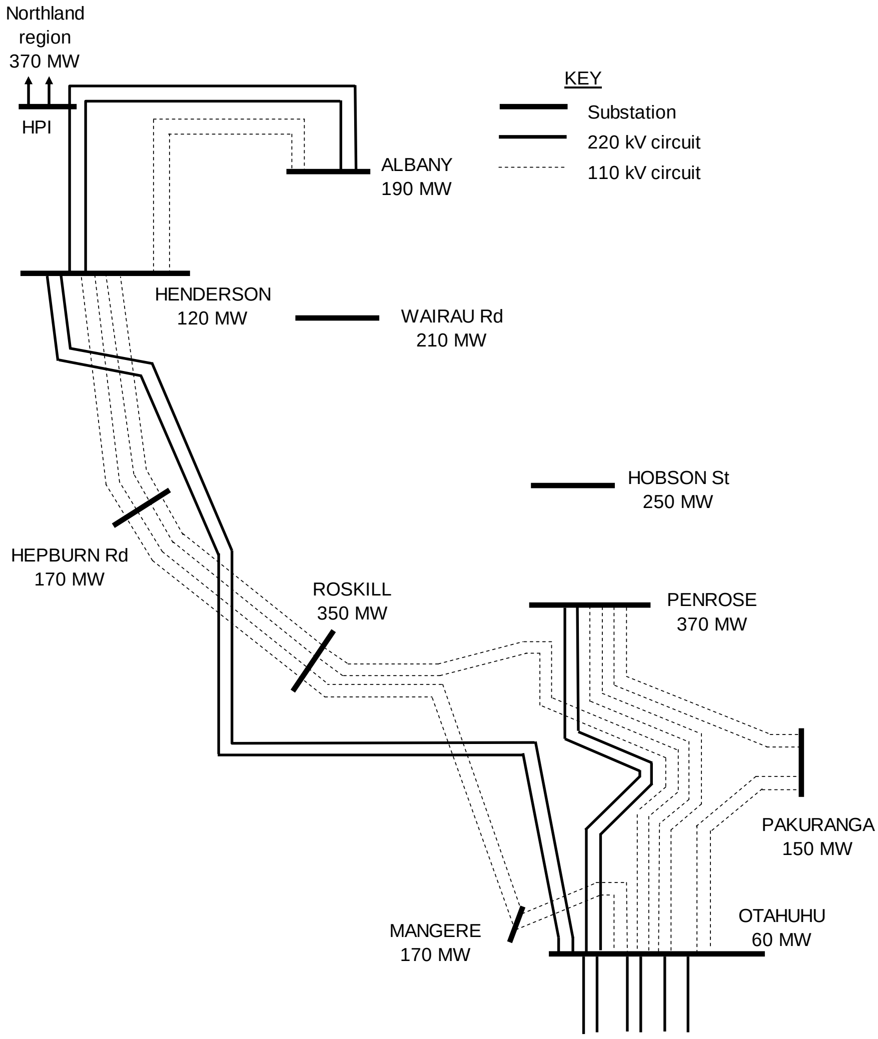

Figure 1 - Existing Transmission System in the Auckland region (simplified)

2.5 Value of Unserved Energy

For comparative purposes, the cost of unserved energy was calculated assuming the following:

- Value of Lost Load = $20,000/MWh; (EGR, part F, clause 8.3.4)
- Restoration time for a major fault = 5 hours (based on experience of 12 June);
- System Operator would be prepared to operate the power system to its non-firm rating during restoration (that is, to an 'n' rather than 'n-1' security level).

The unserved energy values calculated are for comparative purposes only. They are intended to provide an indicative value of diversity, and a means of comparing the various options in light of the impact of high consequence, low probability events such as the loss of a substation.

3 Diversity Analysis

For the purposes of assessing the diversity of this option, the low probability, high consequence contingency of the loss of an entire substation is considered. This type of contingency is rare, but as noted in the introduction, it is not unprecedented. The loss of either Otahuhu substation or Pakuranga substation is considered.

The assessment of the efficacy of the various configuration options is made through quantifying the percentage of Upper North Island load that can supplied following the loss of a substation under the different development options.

3.1 New Line terminated into Pakuranga

This involves terminating the new line at Pakuranga as illustrated in figure 2 below:

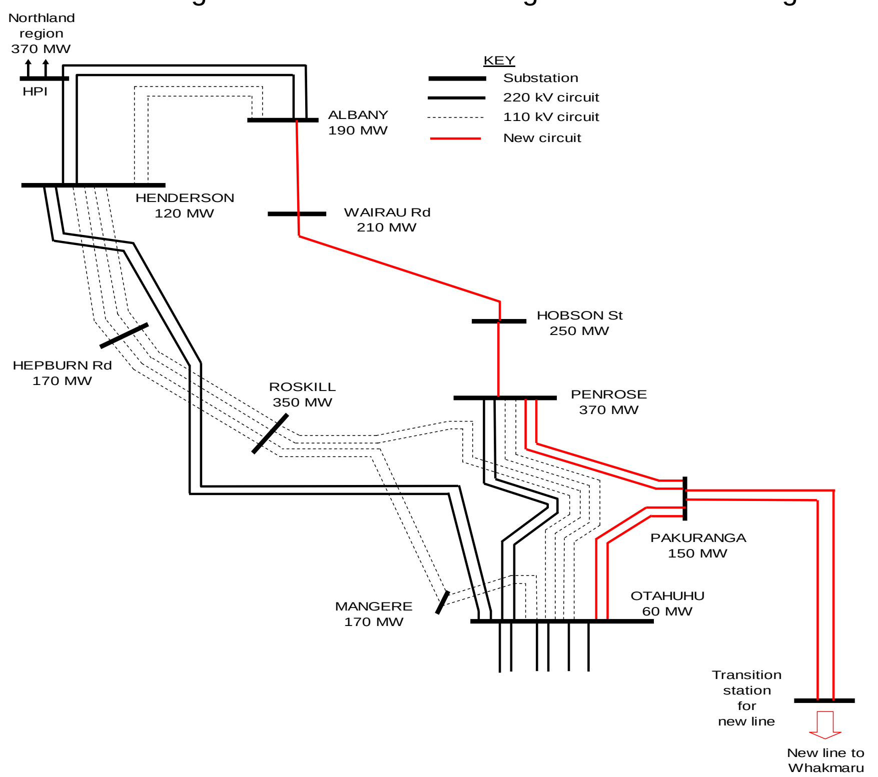

Figure 2 - New line from Whakamaru terminated into Pakuranga substation

3.1.1 Loss of Otahuhu Substation (Otahuhu NOT diversified)

The effect of loosing Otahuhu substation will be dependant on whether or not the substation is split. If there is only a single substation at Otahuhu, then a loss of Otahuhu substation will result in a loss of supply as illustrated in figures 3 and 4 below.

The remaining transmission capacity into Auckland is dictated by the maximum capacity of the cables between the transition station and Pakuranga substation, namely 2 x 660 MVA or 1320 MVA. This equates to about 50% of peak Auckland and Northland load in 2013.

Operators will have considerable flexibility as to how this power is distributed after an event. Possibilities include:

- Auckland CBD and the North Shore
- Auckland CBD and the Northland Region

In either configuration, approximately 50% of the total Auckland and Northland load in 2013 can be supplied following the loss of the entire Otahuhu substation. This equates to approximately $120 M in unserved energy costs for the 50% of load that is interrupted.

Two possible configurations that may result after the loss of Otahuhu substation are illustrated in figures 3 and 4 on the following pages.

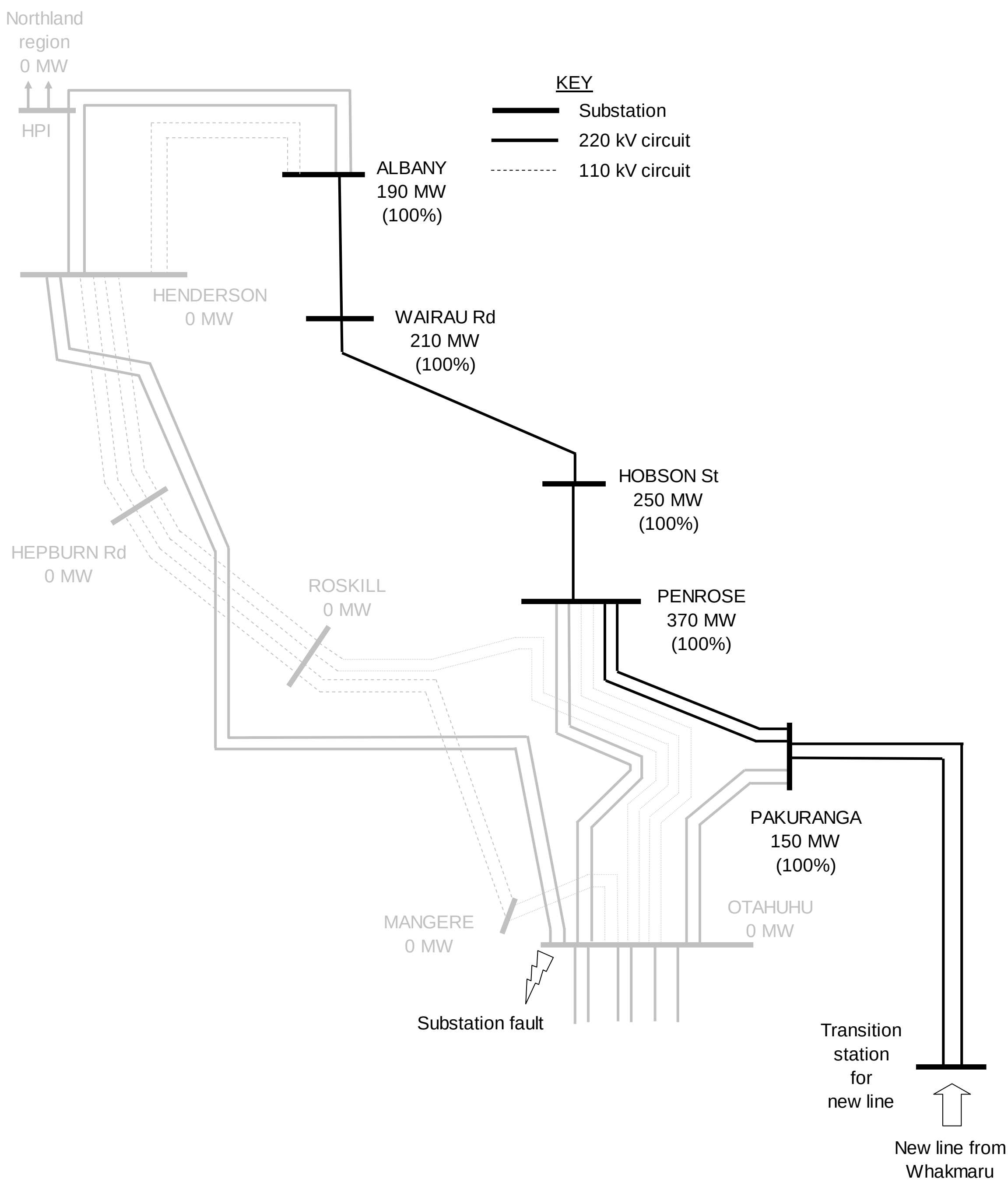

Figure 3 - New line into Pakuranga, following the loss of Otahuhu substation. Shown with supply retained to CBD and North Shore

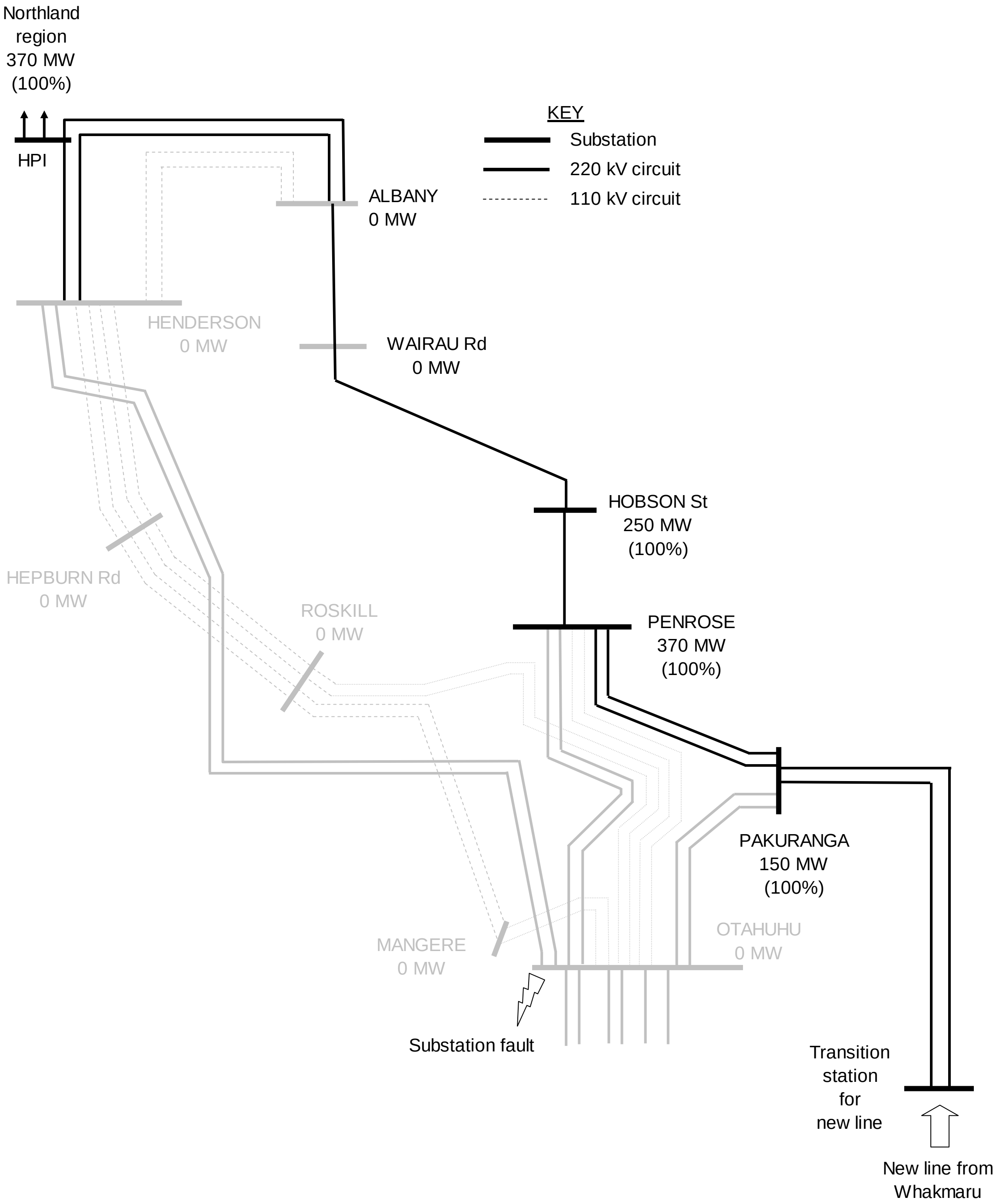

Figure 4 - New line into Pakuranga, following the loss of Otahuhu substation
Shown with supply retained to CBD and Northland

3.1.2 Loss of Otahuhu Substation (Otahuhu diversified)

In this case, the remaining lines will be of sufficient capacity to supply the whole of the Upper North Island region, including Auckland CBD as illustrated in figure 5 below.

This scenario clearly demonstrates the benefits of diversification of Otahuhu substation – even with the new line terminated at Pakuranga. A comparison with the same scenario but without diversification at Otahuhu (section 3.1.1, figures 3 and 4) shows that 100% of loads can be supplied with Otahuhu diversified, as opposed to only 50% if Otahuhu is not diversified.

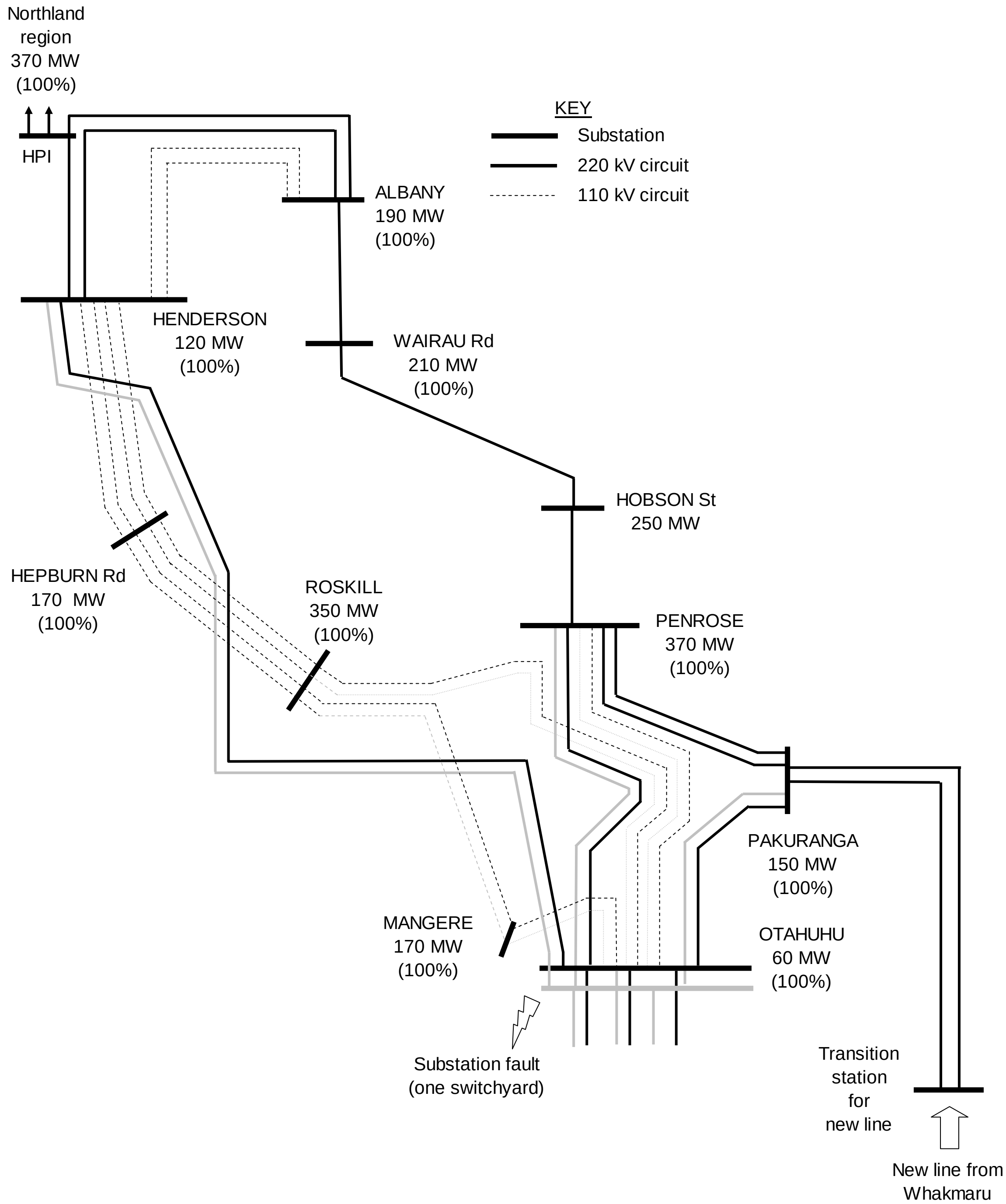

Figure 5- New line into Pakuranga, following the loss of one switchyard at Otahuhu substation.
Otahuhu substation diversified

3.1.3 Loss of Pakuranga Substation

In this case, capacity into Auckland and Northland is dictated by the maximum capacity of the existing lines into Otahuhu. This equates to approximately 2000MW, which is sufficient to supply 90% of total load (excepting Pakuranga substation), or 85% of all loads if the loss of Pakuranga is included. The cost of unserved energy for this option is estimated at approximately $30 M.

Diversifying Otahuhu substation does not affect this scenario.

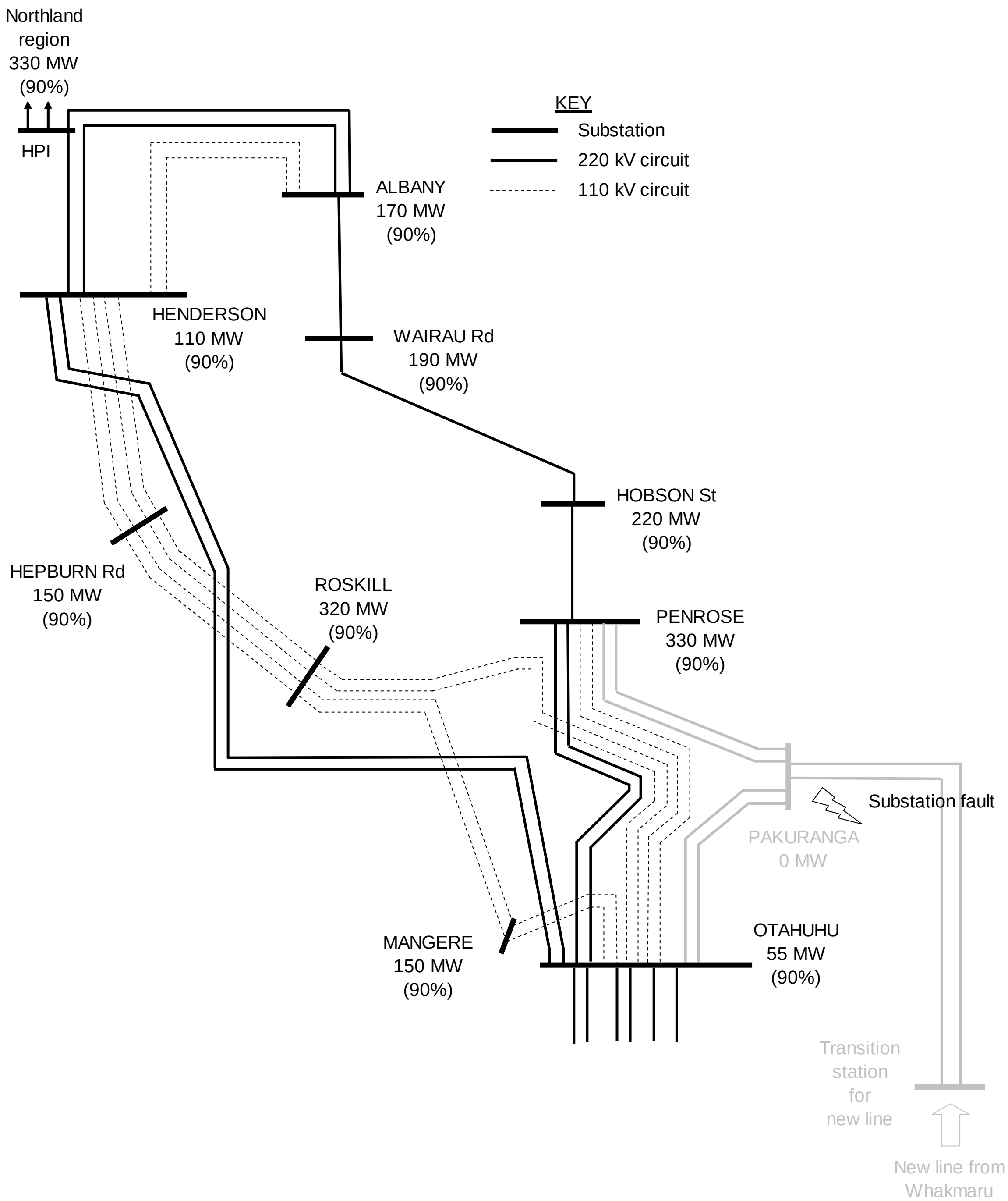

Figure 6 - New line into Pakuranga, following the loss of Pakuranga substation

3.2 New Line Terminated into Otahuhu

In this scenario, Pakuranga remains unchanged as a 110 kV substation supplied from both Otahuhu and Penrose. The arrangement is illustrated in figure 7 below.

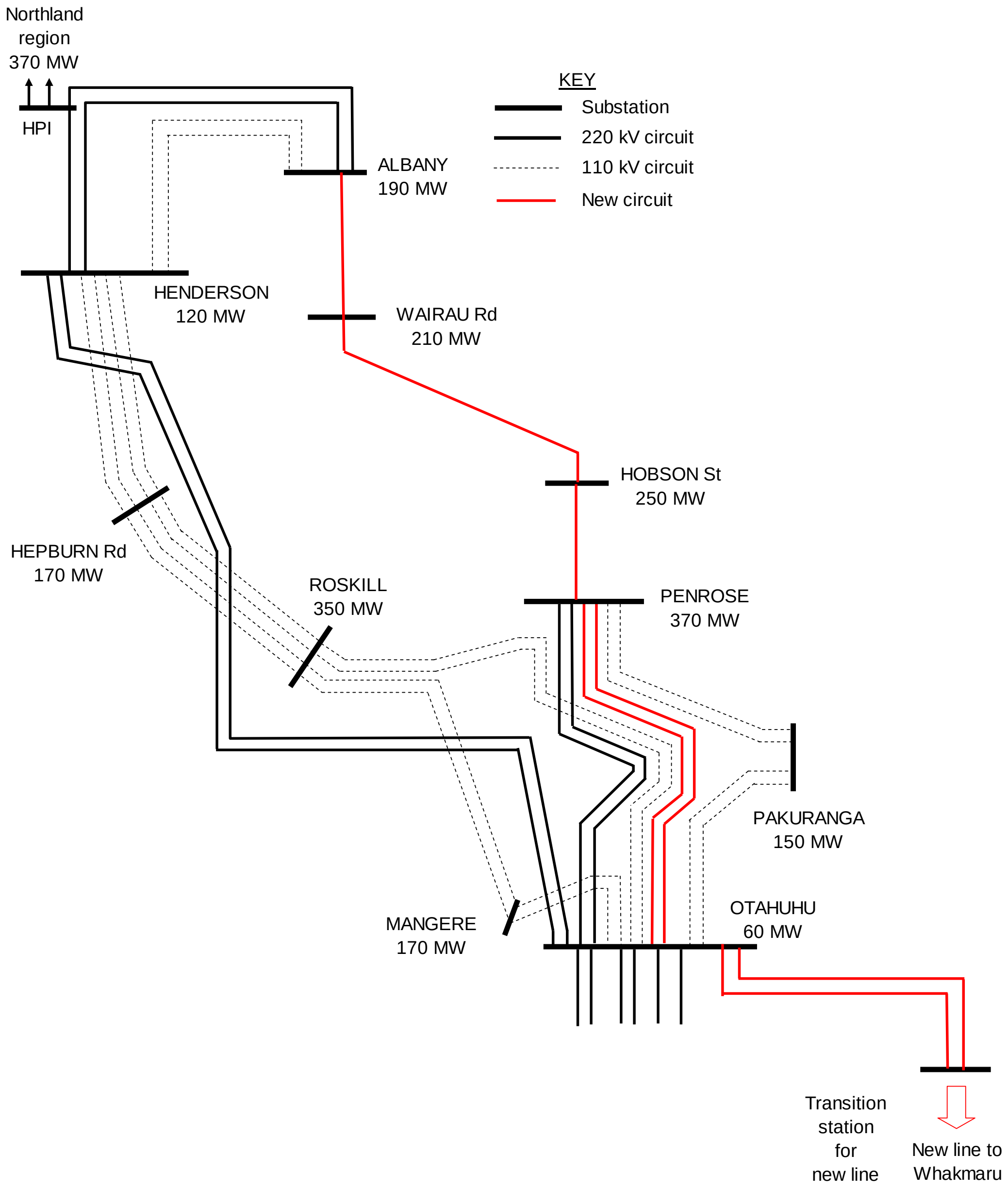

Figure 7 - New line from Whakamaru terminated into Otahuhu Substation

3.2.1 Loss of Otahuhu Substation (Otahuhu NOT diversified)

As there are no alternative transmission routes into Auckland or Northland, the loss of Otahuhu substation will result in a total loss of supply to Auckland and Northland. This equates to approximately $240 M in unserved energy costs.

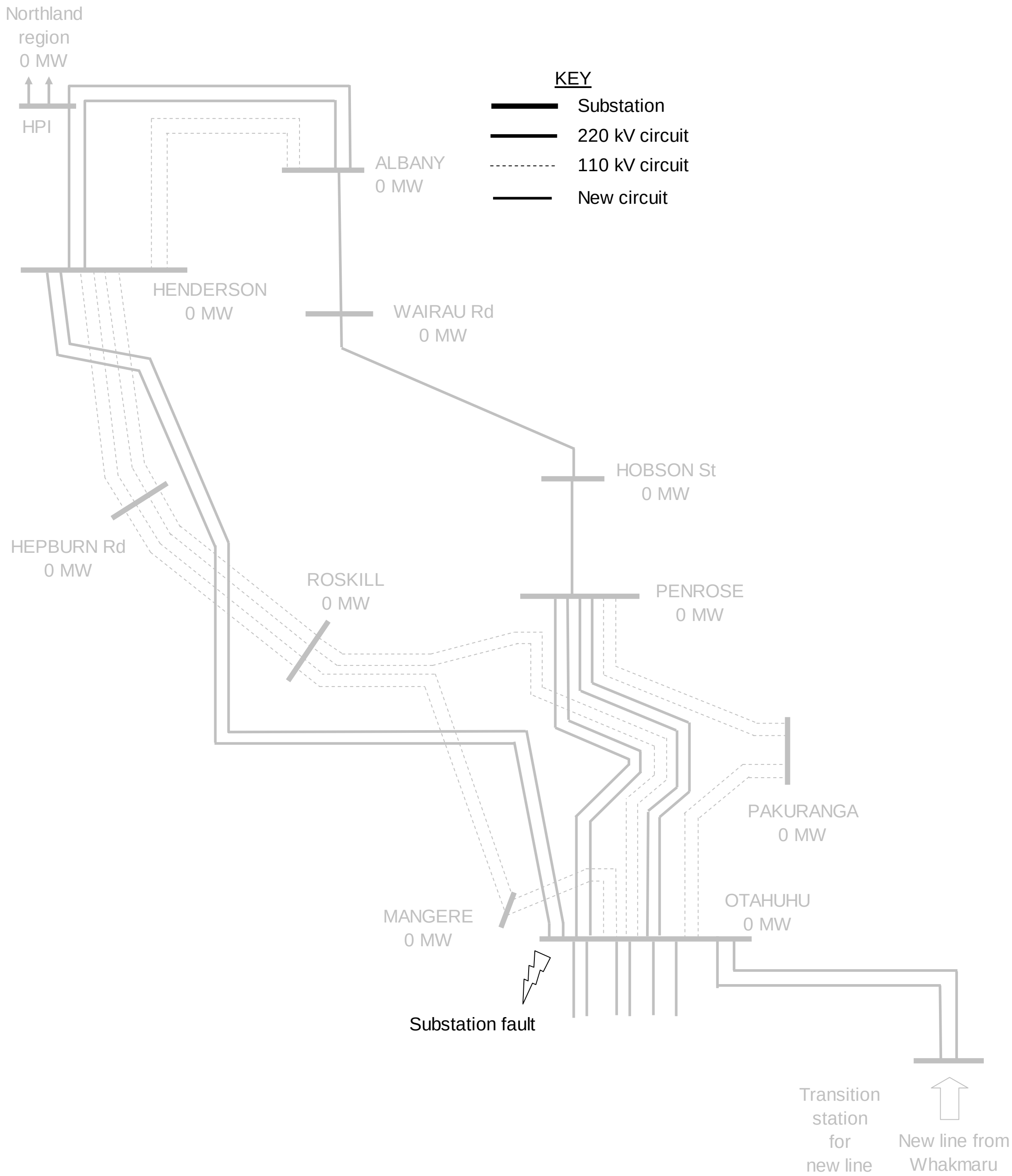

Figure 8 - New line into Otahuhu, following the loss of Otahuhu substation.

3.2.2 Loss of Otahuhu Substation (Otahuhu diversified)

If the Otahuhu substation diversity project were approved and implemented, then the probability of losing the entire Otahuhu substation is greatly reduced.

The limiting factors in this case are the capacities of the existing 220 kV Otahuhu-Penrose line and the existing 220 kV Henderson -Otahuhu line at 400 MVA and 980 MVA per circuit respectively. The cost of unserved energy for this option is estimated at approximately $35 M.

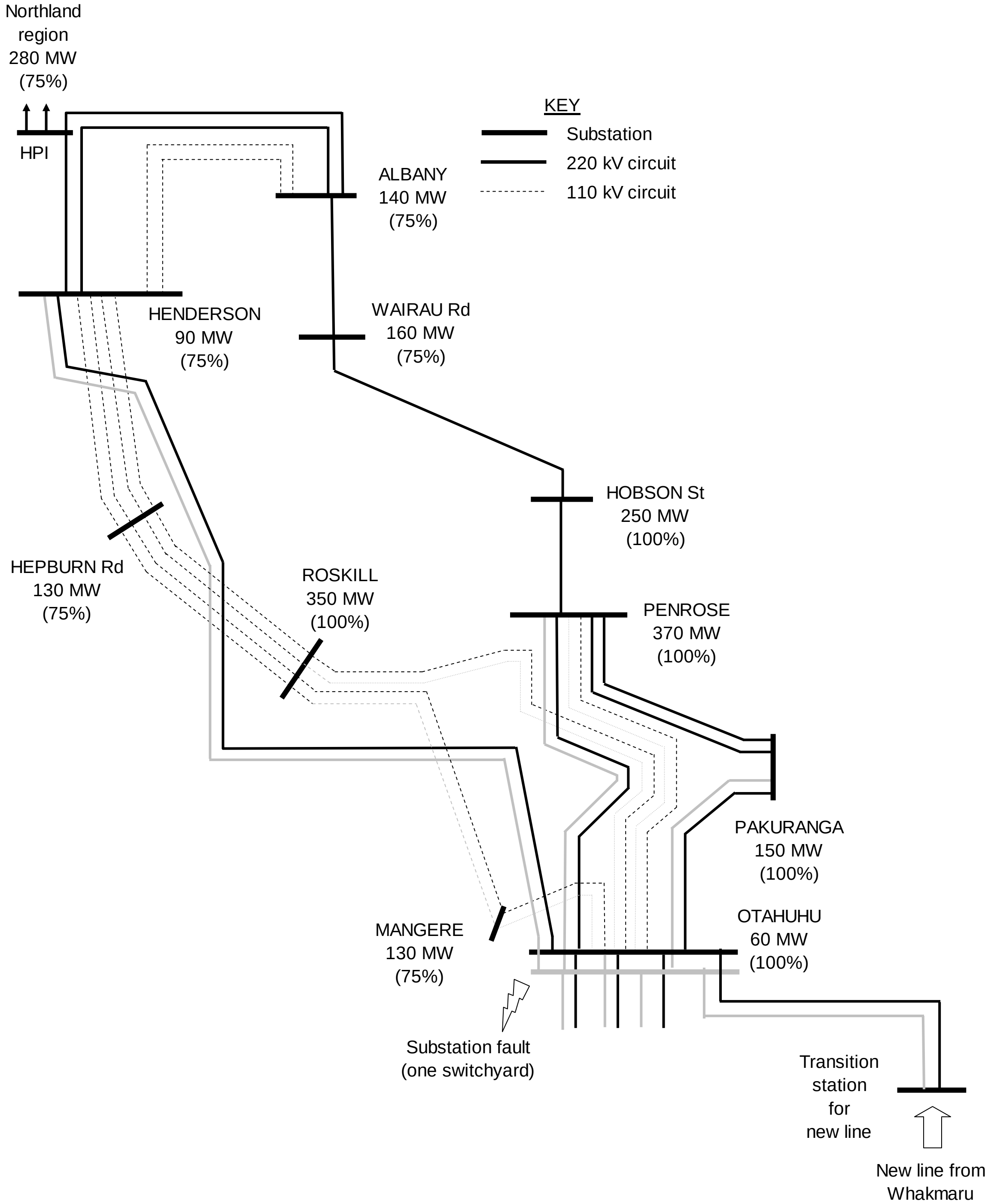

Figure 9 - New line into Otahuhu, following the loss of one switchyard at Otahuhu substation. Otahuhu substation diversified

4 Summary of results

The results are summarised in the tables below:

Contingency	Otahuhu substation diversified	Proportion of Upper North Island load that can still be supplied	Value of Unserved Energy
Loss of Pakuranga substation	Yes	85 %	$30 m
Loss of Otahuhu substation (one switchyard)	Yes	100 %	$ 0 m
Loss of Pakuranga substation	No	85 %	$30 m
Loss of Otahuhu substation	No	50 %	$120 m

Table 4-1. New line terminated into Pakuranga Substation

Contingency	Otahuhu substation diversified	Proportion of Upper North Island load that can still be supplied	Estimated Cost of Unserved Energy
Loss of Otahuhu substation (one switchyard)	Yes	85 %	$35 m
Loss of Otahuhu substation	No	0 %	$240 m

Table 4-2. New line terminated into Otahuhu Substation

These results show that significant gains in transmission reliability for the Upper North Island can be attained if the new line proposed by Transpower terminates into Pakuranga substation. If this were implemented, then the total loss of either Otahuhu or Pakuranga substation will, at worst, result in the loss of 50% of peak Auckland and Northland load in 2013.

These results are further improved if Otahuhu substation is diversified as well. In this case, at worst only 15% of Upper North Island load will be lost following a substation contingency, compared to 50% if Otahuhu is not diversified.

Terminating the new line into Otahuhu substation will only provide an improvement in diversity if Otahuhu substation is diversified as well. If this were done, then up to 20% of Upper North Island load would be lost following a switchyard contingency.

However, if a site wide event were to result in the loss of both switchyards at Otahuhu, or if Otahuhu substation is not diversified, then a total loss of supply will result.

5 Conclusions

There are two key opportunities available to provide diversity:

- o Establish a separate substation at Otahuhu; and
- o Terminate a new supply from the south at Pakuranga, establishing a new supply substation for Auckland.

If both steps are taken, a major problem at either Otahuhu or Pakuranga would still leave sufficient capability to supply the central business district and more than 80% of the Auckland load. The most severe substation outage would result in a possible unserved energy cost of about $35M.

If Pakuranga was established but the Otahuhu substation was ***not*** diversified, the possible unserved energy costs could range between $30M and $120M for a substation outage.

If neither opportunity was taken (ie new supply from the south goes to Otahuhu and Otahuhu is ***not*** diversified), the possible unserved energy costs could range as high as $240M with the total loss of Auckland supplies.

6 Additional Information

6.1 Duration of Outages

Should there be a failure resulting in the loss of a substation, there is the possibility that all load north of Auckland would be lost which could cause subsequent cascade failure resulting in lost load in all areas north of Whakamaru. This would include the Waikato and Bay of Plenty regions.

The System Operator provided indicative duration times for such outages resulting from a complete loss of load. These were estimated under best and worst case conditions as follows:

Outage hours	Worst case (hours)	Best case (hours)
WKM North (incl BoP)	10	8
Upper North Island	7	5

Table 6-1. Indicative outage duration times

From the above table, it can be seen that the 5 hour outage time used in the analysis was at the conservative end of estimates.

6.2 Unserved Energy Amounts

The unserved energy estimates used in the analysis were high level and based on a peak load level of 2,400 MW sustained over a 5 hour outage period resulting in potential unserved energy of 12,000 MWh.
Assuming a value of un-served energy of $20,000/ MWh, expected unserved energy from a 5 hour outage causing 100% loss of load to Auckland and Northland was estimated at $240 million in 2013.

This assumption has since been tested using the 5 hour peak load period from 2006. The 5 hour peak load occurred on 23 June 2006 from 7.30 am onwards and totalled 9,867 MWh.

Growing this by the EC's draft prudent forecast growth rates gives a forecast demand of 11,797 MWh in 2013. This is very close to the approximation of 12,000 MWh used in the analysis.

6.3 Probability of Failure

If there is only a single substation at Otahuhu (Otahuhu NOT diversified), the probability of a 220kV AIS mechanical, spring based circuit breaker major failure[2] – such as those used in Otahuhu – is approximately once per 38.6 years or 2.6%. Such a failure would cause the loss of the Otahuhu substation.

This failure rate could only be applied to the cases where Otahuhu substation is NOT diversified.

It is very difficult to estimate what the probability of failure would be in the cases where the Otahuhu substation is diversified, since it depends heavily on the individual configuration of each substation. The rate of independent concurrent failure is negligible. The substation would be designed so as to minimise the chances of all foreseen common cause failures, but the actual rate is difficult to estimate. Given this, no attempt has been made to estimate the expected value of un-served energy resulting from such a failure.

[2] Based on CIGRE survey data.

6.4 Appendant Results

An additional column has been added to the original results tables to show the expected unserved energy which allows for an estimated probability of outage occurrence.

Contingency	Otahuhu substation diversified	Proportion of Upper North Island load that can still be supplied	Value of Unserved Energy	Expected Value of Unserved Energy
Loss of Pakuranga substation	Yes	85 %	$30 m	Not calculated – refer section 6.3
Loss of Otahuhu substation (one switchyard)	Yes	100 %	$ 0 m	Not calculated – refer section 6.3
Loss of Pakuranga substation	No	85 %	$30 m	$0.78 m
Loss of Otahuhu substation	No	50 %	$120 m	$3.11 m

Table 6-1. New line terminated into Pakuranga Substation

Contingency	Otahuhu substation diversified	Proportion of Upper North Island load that can still be supplied	Value of Unserved Energy	Expected Value of Unserved Energy
Loss of Otahuhu substation (one switchyard)	Yes	85 %	$35 m	Not calculated – refer section 6.3
Loss of Otahuhu substation	No	0 %	$240 m	$6.22 m

Table 6-2. New line terminated into Otahuhu Substation