TRANSPOWER

North Island 400 kV Upgrade Project

Investment Proposal

Part II – Establishing the Need for New Investment

1 Summary

Part II of Transpower's submission demonstrates the need for the proposed investment by analysing demand and generation forecasts against Transpower's current grid reliability standards. The analysis concludes that there is a risk of electricity demand not being supplied into the upper North Island from 2010 and that new investment is required to maintain security of supply into the region.

Transpower's needs analysis draws on a number of key inputs which are described below and are contained in section 2 to 5 of this Part II:

a) *Forecast electricity demand (section 2)*

Demand forecasts (including sensitivity analysis) are developed for all grid exit points in the upper North Island. These demand forecasts are based on the Electricity Commission's national electricity demand forecast for the next 40 years.

b) Forecast electricity generation (section 3)

Five generation scenarios are used to identify existing generation and the range of possible future generation in the upper North Island region.

c) Grid Reliability Standards (section 4)

The transmission planning criteria sets out Transpower's current grid reliability standards (noting its consistency with the Electricity Commission's grid reliability standards).

d) Existing and Proposed Power System (section 5)

The parameters of the current power system including generation capacity and reliability and transmission limits.

2 Forecast Electricity Demand

Transpower has developed demand forecasts for each grid exit point to enable it to undertake the power system analysis required to determine the need for investment and to complete the economic analysis of transmission and non-transmission alternatives. This section sets out the basis on which the demand forecasts were developed for the upper North Island.

2.1 Electricity Demand Growth Forecasts

Transpower utilised the Electricity Commission's 2005 national electricity consumption 40 year forecast as the basis of creating the necessary demand forecasts for the power system analysis. This national forecast is set out in Figure 2-1.

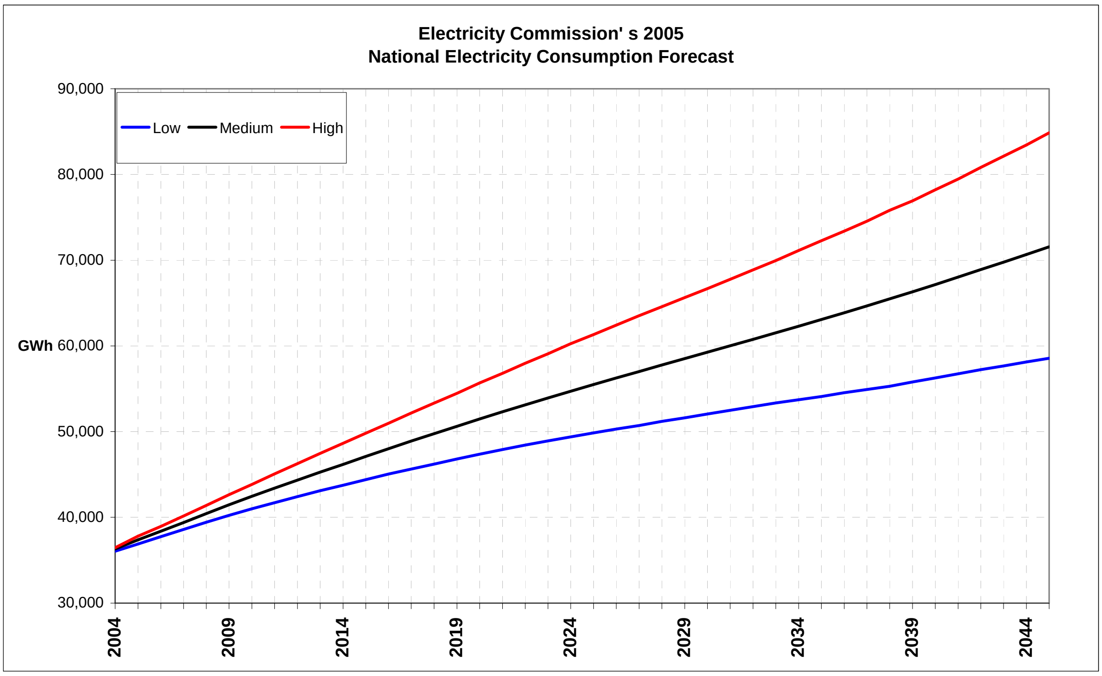

Figure 2-1: National Electricity Consumption Forecast

2.1.1 Regional Allocation Methodology

Transpower used the national electricity consumption forecast to derive a forecast of the half hourly average peak demand known as the After Diversity Maximum Demand (or ADMD) at all grid exit points by using a regional allocation methodology, as shown in Figure 2-2. The ADMD forecast is derived by using the following factors:

- Allocation of national demand across all regions
- A review of the historical peak demand
- An assessment of distributed generation uptake.

The allocation of national growth in demand to regions was completed on the basis of forecast of regional population growth. Regional growth projections were obtained from Statistics New Zealand.

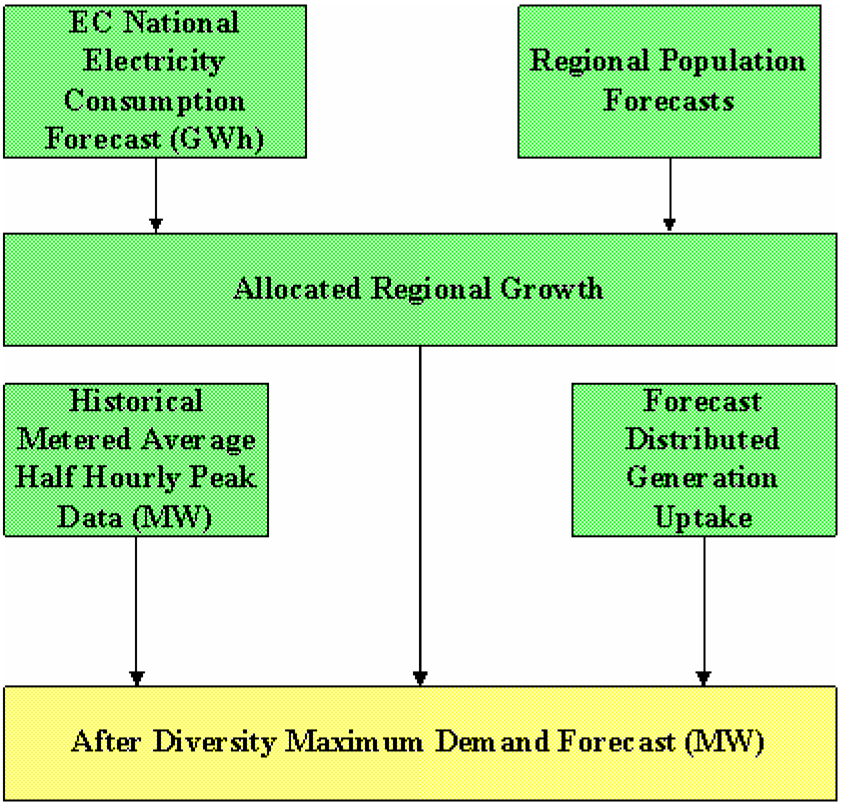

Figure 2-2: High Level Process for Deriving Transpower's After Diversity Maximum Demand Forecast

2.1.2 Small Scale Distributed Generation

The national electricity consumption forecast, is a forecast of gross electricity consumption, including that delivered from the grid and supplied locally from small scale distributed generation. Transpower plans on the basis of the load that needs to be supplied from the grid and consequently, Transpower's regional demand forecast is derived including an implicit assumption about the uptake of small scale distributed generation in the future. The expected contribution from local small scale distributed generation has been deducted from the gross consumption forecast at grid exit point level.

A forecast of the uptake of small scale distributed generation is made based on projected technology and electricity production costs under various manufacturing and commercial conditions (e.g. available sources of energy, industrial work patterns). An industry profile is used to assess those applications where distributed generation may be cost effective compared to grid delivered electricity. Small scale distributed generation is projected to increase from its estimated current uptake of 4% to a level equivalent to 5% of the total forecast peak demand by the end of the forecast period (2046).

2.1.3 Annual Demand Variations and Establishing a Baseline

While demand in the upper North Island has trended upwards over time, there can be substantial fluctuations year on year from an expected average. These variations may be caused by effects such as ambient temperature changes. In the case of a city such as Auckland, it is usual to expect a temperature related demand sensitivity of approximately 25 MW per °C for variations of typical winter temperatures (i.e. 50 MW for 2°C). This is illustrated in Figure 2-3 which shows the volatility of the demand observed during the period 1997 – 2004 with actual demands varying as much as +/-40 MW from the average trend line.

In order to establish a reasonable starting point for demand forecasting, a baseline for the peak demand forecast was derived using the trend of actual average half hourly metered information between 1997 and 2004. This approach contrasts with one which assumes the base demand as the peak demand observed during one particular year which may over or underplay the impact of random variations in the annual peak demand.

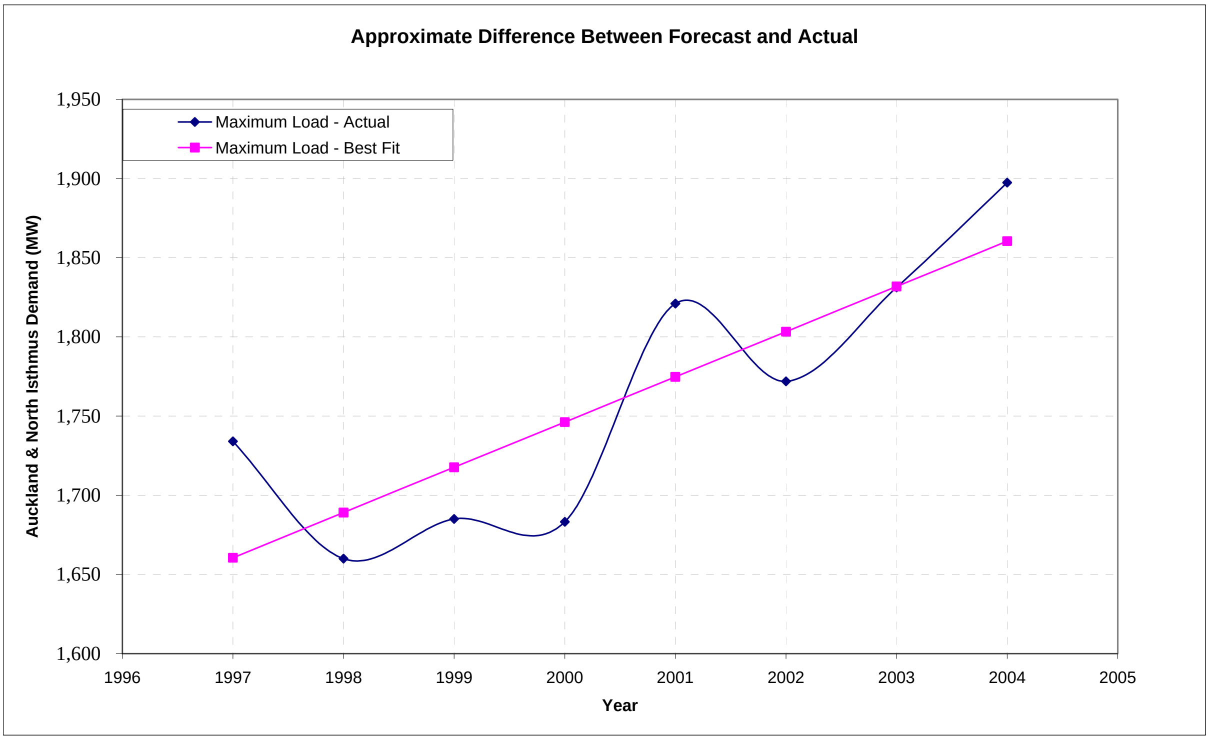

Figure 2-3: Difference Between Forecast Trend and Actual Demand

2.1.4 Average Half Hourly ADMD Forecast

Another key assumption in the projections for the base demand scenario is that the rate of growth in peak demand matches the rate of growth in gross electricity consumption.

The resulting ADMD forecast is a forecast of the half hourly average peak demand, as opposed to a forecast of the instantaneous peak demand. This difference is discussed in more detail in Section 2.1.5.

The upper North Island region encompasses the area north of Bombay. Figure 2-4 shows the average half hourly ADMD forecast for the upper North Island regions.

A complete table of low, medium and high forecast data for the combined regions can be found in Appendix II-A. The load forecasts show that annual peak demand in the region by 2010 will be approximately 2265 MW under a medium growth forecast and 2345 MW under a high growth forecast.

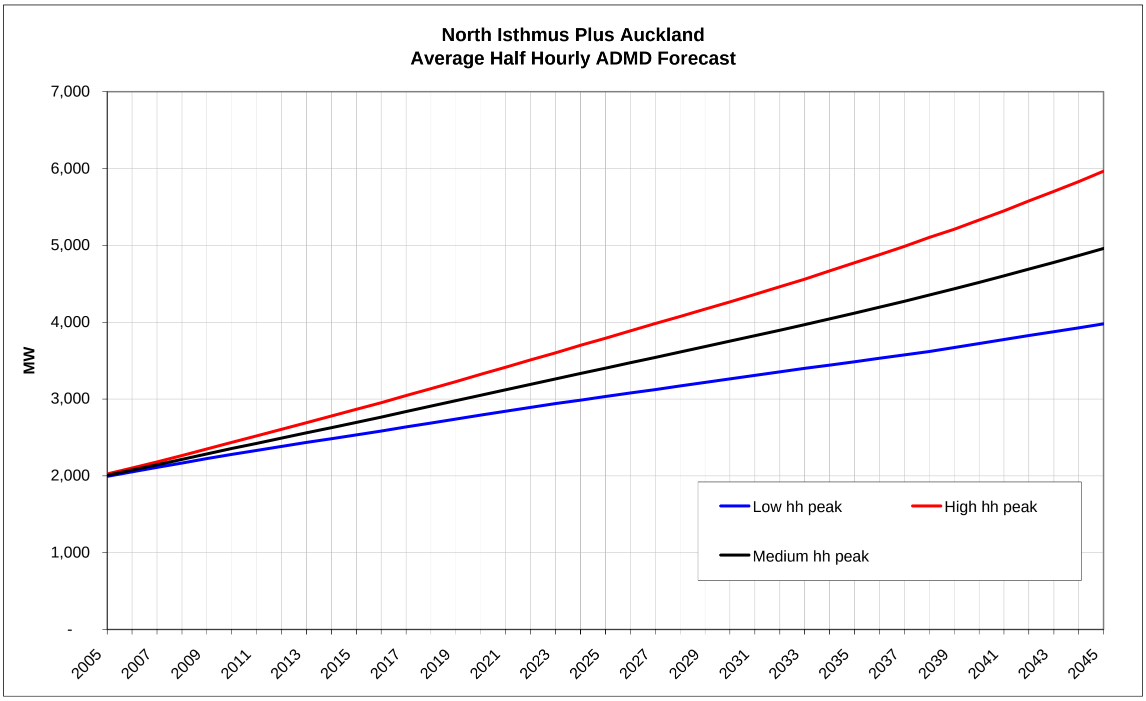

Figure 2-4: Upper North Island Forecast Half Hourly Average Peak Demand

2.1.5 Instantaneous ADMD Forecast

Transpower considers that it is prudent to base load forecasting methods upon actual system demand as opposed to half hourly average metered demand data as this provides a more stable basis for forecasting. Metering is a reliable source of information and is correlated with electricity billing practices. However, these forecasts only provide a long term view of half hourly average demands and do not take into account the short term volatility, (e.g. instantaneous variations in the load) or the medium term volatility (e.g. variations due to unexpected seasonal changes) of grid exit point requirements.

Short-term, or instantaneous demand varies within the “half hourly average” figure and in the case of the greater Auckland area and north regions, variations of ±50 MW are common. This is illustrated in Figure 2-5, which shows the actual instantaneous system demand, as represented by metered data, for a typical Winter’s day. The instantaneous peak demand, in the upper North Island region can be 50 MW higher than the average metered data.

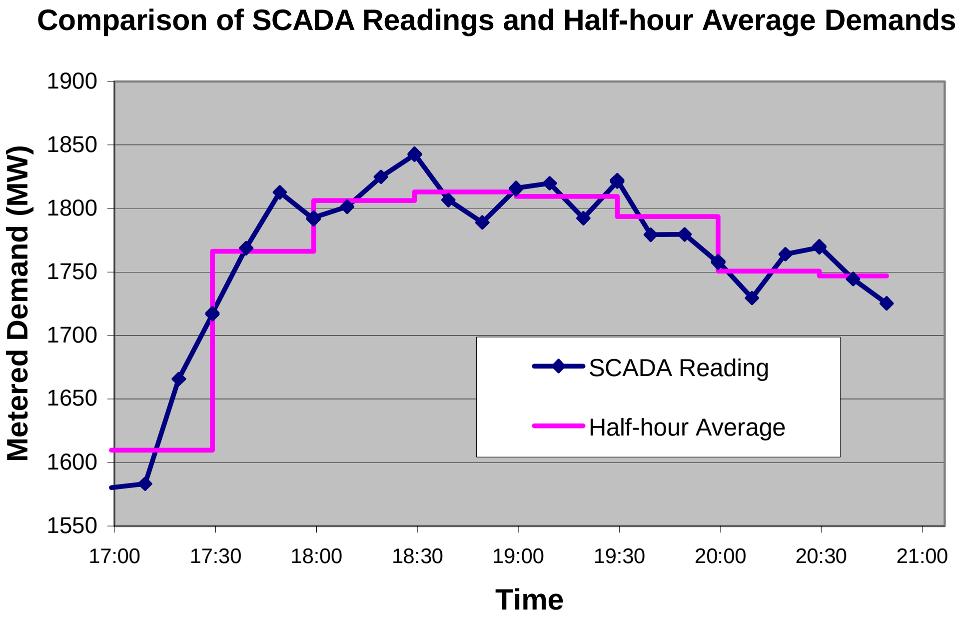

Figure 2-5: Metered Data versus Half Hourly Average Demand Comparison

2.1.6 Electricity Commission Comparison

The Commission has recently published its regional peak demand forecast in the Statement of Opportunities. The methodology the Commission has employed is almost identical to Transpower's with the following key differences:

1. The Commission does not assume a future uptake of distributed generation;
2. The Commission has used a different base year to Transpower from which to forecast.

Nevertheless, both approaches by the Commission and Transpower deliver consistent outcomes.

The chart below compares the following:

1. The Commission's peak demand forecast which excludes any assumption about future distributed generation;
2. Transpower's demand forecast excluding any uptake of future distributed generation;
3. Transpower demand forecast used in the transmission planning assumptions outlined in this proposal. The forecast includes an assumption about the uptake of distributed generation in the future.

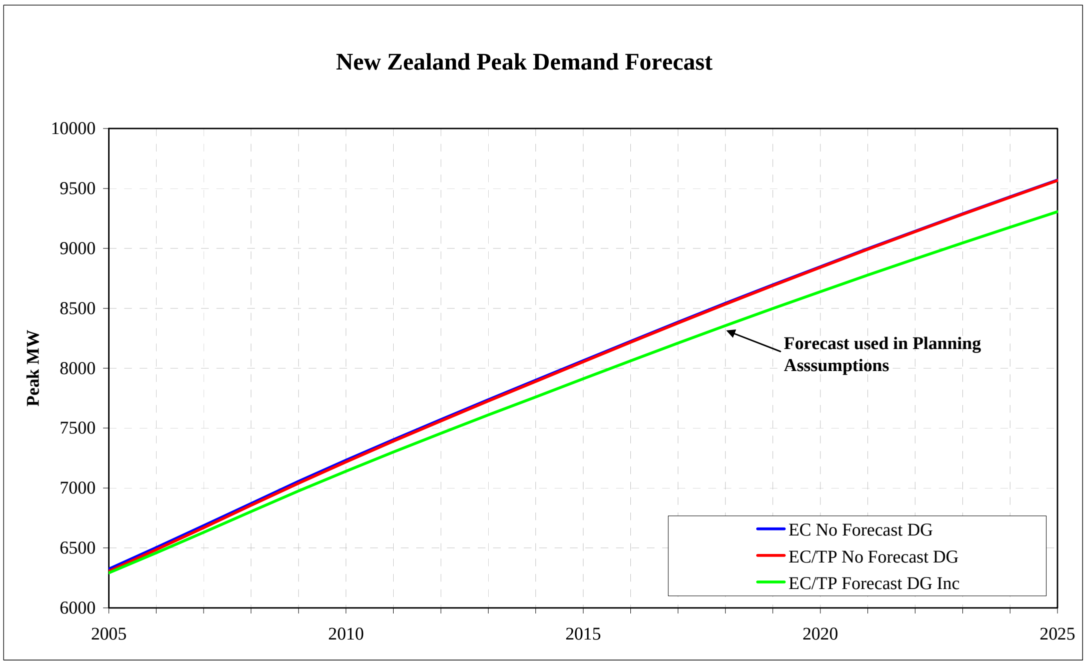

Figure 2-6: Commission and TPNZ Peak Demand Forecast Comparison

The above chart shows that on a "like for like" basis, ie excluding any assumption about distributed generation uptake, there is no material difference between the Commission's forecast and the forecast Transpower used for its planning analysis.

Transpower also considers that the differences between the demand forecast used in this analysis and the Commission's demand forecast, (which is slightly higher), are immaterial to both the outcomes of the need for and timing of new investment and the economic analysis.

Further information on this process can be found in the supporting document: "North Island 400 kV Project Planning Assumptions – Demand and Generation Forecasting."

2.1.7 Demand Forecast Summary

In summary, the demand forecast utilised for this submission has been based on the following:

- The Electricity Commission's national consumption forecast.
- A conversion of the national forecast to regional forecasts.
- A baseline starting forecast for 2005 based on average growth over the last seven years.
- An allowance for the effect of year by year demand fluctuations from the baseline forecast (40 MW) and the effect of average metered demand versus actual demand (50 MW) by the addition of 90 MW to the baseline forecast.

Figure 2-7 shows the instantaneous peak demand forecast (as the dashed line) which has been derived from the above process and has been used in this submission. Appendix II-A provides a detailed table of the year by year demand forecast from 2005 until 2045.

Further information on this process can be found in the supporting document titled, "North Island 400 kV Project Planning Assumptions – Demand and Generation Forecasting".

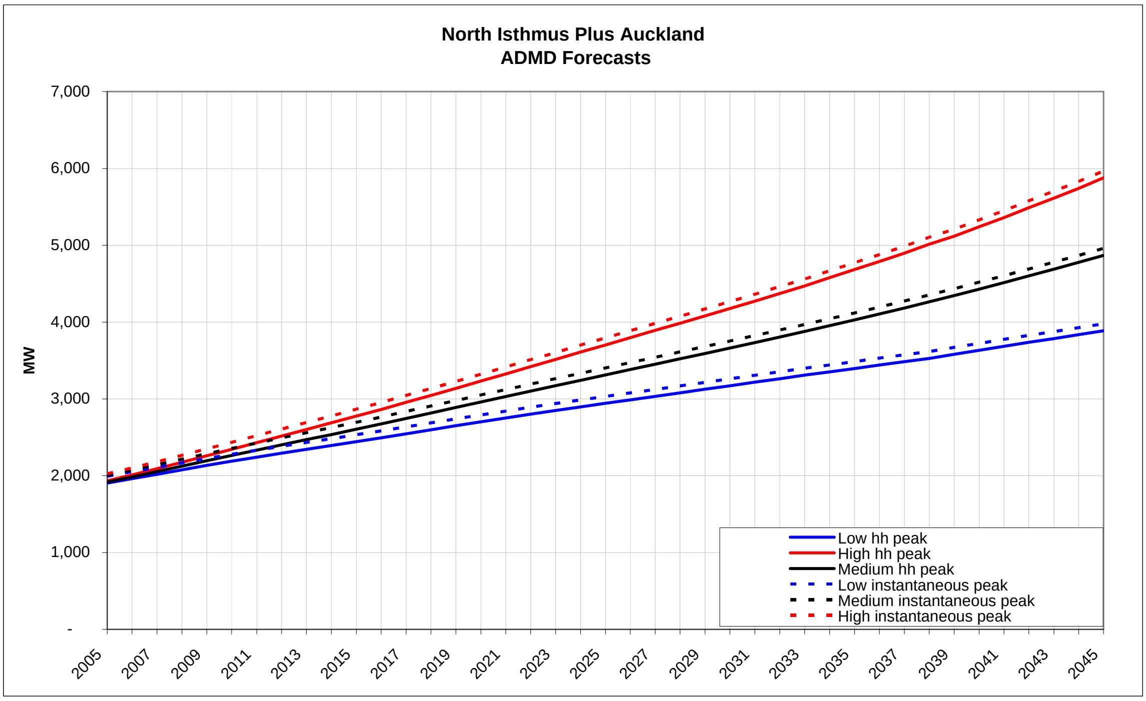

Figure 2-7: Upper North Island Average Half Hourly Forecast Demand

3 Generation Scenarios

Transpower has developed five generation scenarios to identify the range of possible generation forecasts in the upper North Island region over the next 40 years.

The generation scenarios contained within this submission are based on a set of generation scenarios developed by Transpower over the period 2003 – 2004 and have been modified where additional information has become available. These generation scenarios were used for assessing the robustness of Transpower's grid upgrade alternatives against a range of future generation developments.

The type and location of generation capacity was determined by the scenario, eg Scenario 1 assumed the majority of new North Island generation was located in:

- areas where there is a high probability of further gas being discovered, ie Taranaki, East Coast North Island;
- areas on the main gas transmission network, ie Huntly, Otahuhu;
- areas where there is a high probability of new gas fired co-generation stations such as Marsden.

Generation requirements were established, at five yearly intervals, assuming a 1-in-20 dry year requirement i.e. sufficient generating plant is available to ensure that a dry year (modelled as whenever hydro reserves fall below 300 GWh of generation) only occurs once every twenty years on average.

Transpower's 2003 - 2004 generation scenarios are regarded as suitable for this analysis as they reflect current knowledge of New Zealand's energy supplies and include sufficient generation to meet the electricity consumption forecast detailed in Section 1.

Scenario 1 – Unconstrained inputs ("Burn Gas")

Scenario 1 reflects an environment where there are no resource constraints. In this scenario, gas is plentiful and cheap, and the first choice of input for electricity generation. It is assumed that gas is only available for generation in the North Island. The HVDC is constrained to its existing capacity in this scenario, limiting the amount of North Island based gas-generated electricity that can be transmitted to the South Island. Some gas reserves have been discovered off the coast of Canterbury, but these are not commercial and are not supported by existing infrastructure. Generation in the South Island is provided through a mix of hydro generation and coal. Limited wind and geothermal generation have been included as has limited hydro in the North.

Scenario 2 – Gas constrained ("Burn Coal")

Scenario 2 portrays a future where significant gas is not found, but where coal is an acceptable and attractive alternative. It is assumed that existing gas generation will be retained, either as gas or an alternative fuel type, in its current location. The location selected for new coal-based generation depends on the island it is located in. In the North Island coal generation has been located at, or close to, major port facilities or near known coal reserves in the Waikato area. In the South Island coal generation has been located at, or close to, known coal reserves. This scenario also introduces more wind generation in the North Island than in Scenario 1, to reflect a marginal response associated with anticipated higher costs in the North Island.

Scenario 3 – Carbon constrained ("Renewables")

This scenario reflects a future in which carbon fuels such as gas and oil are uneconomic due to a combination of resource availability, and carbon constraints or taxes imposed as a result of environmental policy. Generation is provided mainly through a mix of hydro, wind, geothermal, and biomass. In order to provide the quantities of generation required, it is assumed that significant hydro development remains viable despite local environmental issues. In later years significant amounts of new biomass based generation are introduced in order to meet North Island demand, given the assumed HVDC constraint.

Scenario 4 – Carbon constrained and HVDC unconstrained ("Southern Hydro")

This scenario is similar to Scenario 3 in that it reflects a future where generation is primarily provided through renewable sources. In this case though, it is assumed that the HVDC capacity is unlimited so as to enable transport of electricity from hydro sources in the South to the North Island. The intent of this is to provide a scenario with a larger proportion of hydro-generation in the South Island, as opposed to Scenario 3 where the HVDC constraint results in biomass renewables being installed in the North Island to meet demand.

Scenario 5 – Reduced South Island Demand ("Reduced South Island Demand")

In Scenario 5, South Island demand is reduced, in steps, by 200 MW in 2015, 2019 and 2023 so that by 2023, a total of 600 MW of demand has been dropped in the South Island. Given that the HVDC link is assumed to remain constrained to its current limit of 1,040 MW North and 620 MW South, the extent of new North Island capacity was capped by how much was required to meet forecast peak demand in the North Island. Therefore, the reduction in new generation capacity to be installed mainly occurs in the South Island.

Table 3-1 shows the new installed generation capacity in each region under the five generation scenarios.

Scenario 1 - Additional New Generation Capacity Installed

MW	N. Isthmus	Auckland	Waikato	BOP	Hawke Bay	Taranaki	Central	Wellington	WstCst	Nelson	SthCant	Canterbury	Otg/ Slnd	**Total**
2010	32	393	440	-	-	18	-	22	-	-	-	60	294	1,258
2015	32	393	618	-	119	399	-	22	212	-	-	120	371	2,285
2020	32	929	618	-	119	399	-	379	212	-	-	120	448	3,254
2025	270	1,226	618	-	119	815	-	591	365	-	-	239	448	4,692
2030	570	1,226	840	-	357	815	244	591	365	-	-	239	686	5,934
2035	808	1,226	1,118	278	357	815	244	591	365	-	-	239	686	6,728
2040	808	1,226	1,790	278	357	815	661	591	365	-	-	239	686	7,816

Scenario 2 - Additional New Generation Capacity Installed

MW	N. Isthmus	Auckland	Waikato	BOP	Hawke Bay	Taranaki	Central	Wellington	WstCst	Nelson	SthCant	Canterbury	Otg/ Slnd	**Total**
2010	399	-	440	-	-	18	-	22	119	-	-	-	200	1,198
2015	982	-	618	-	-	18	-	22	119	-	-	200	200	2,159
2020	982	-	975	-	357	18	-	22	119	-	-	200	498	3,171
2025	1,280	-	1,570	36	393	18	244	234	476	-	-	200	664	5,115
2030	1,577	-	1,792	36	393	18	488	234	476	-	-	200	1,021	6,236
2035	1,577	-	2,070	202	393	18	488	234	476	-	-	200	1,021	6,680
2040	1,577	-	2,378	202	393	368	488	234	595	-	-	200	1,498	7,933

Scenario 3 - Additional New Generation Capacity Installed

MW	N. Isthmus	Auckland	Waikato	BOP	Hawke Bay	Taranaki	Central	Wellington	WstCst	Nelson	SthCant	Canterbury	Otg/ Slnd	**Total**
2010	32	393	440	-	-	18	-	22	62	88	-	62	181	1,298
2015	204	393	696	36	113	18	-	22	62	165	-	217	588	2,514
2020	204	393	696	66	383	166	441	22	262	165	77	371	858	4,104
2025	307	473	898	305	454	226	640	446	262	319	77	371	1,012	5,788
2030	393	473	1,009	342	514	374	762	446	262	627	385	483	1,134	7,202
2035	512	473	1,287	509	715	374	821	446	262	627	385	622	1,174	8,205
2040	512	592	1,769	564	953	493	940	565	262	781	385	622	1,174	9,611

Scenario 4 - Additional New Generation Capacity Installed

MW	N. Isthmus	Auckland	Waikato	BOP	Hawke Bay	Taranaki	Central	Wellington	WstCst	Nelson	SthCant	Canterbury	Otg/ Slnd	**Total**
2010	32	393	440	-	-	18	-	22	62	-	275	92	-	1,334
2015	204	393	518	-	78	18	-	22	62	77	529	92	585	2,577
2020	204	393	518	31	334	166	441	22	292	77	606	246	854	4,184
2025	247	473	696	31	359	166	640	422	292	390	606	246	1,470	6,038
2030	333	473	807	68	359	314	762	422	292	698	914	359	1,745	7,546
2035	333	473	1,084	235	382	314	762	422	292	698	914	497	2,245	8,652
2040	333	473	1,448	290	382	314	762	422	292	1,006	1,452	497	2,553	10,225

Scenario 5 - Additional New Generation Capacity Installed

MW	N. Isthmus	Auckland	Waikato	BOP	Hawke Bay	Taranaki	Central	Wellington	WstCst	Nelson	SthCant	Canterbury	Otg/ Slnd	**Total**
2010	70	357	357	50	-	-	30	22	-	29	-	62	200	1,177
2015	145	357	624	50	-	381	103	72	-	121	-	62	335	2,250
2020	145	379	624	127	250	531	353	122	-	121	-	62	335	3,049
2025	295	509	884	294	450	531	653	322	-	204	-	62	410	4,613
2030	647	509	1,034	353	450	556	653	322	-	204	-	62	460	5,250
2035	766	509	1,502	353	569	675	712	441	-	204	-	201	783	6,716
2040	766	628	1,921	464	688	675	712	441	-	466	-	201	783	7,746

Table 3-1– New Generation Capacity by Region

Full details of the generation scenarios can be found in the Transpower document: "North Island 400 kV Project Planning Assumptions – Demand and Generation Forecasting".

3.1 Summary of Generation in the Auckland and North Isthmus region

The power system analysis and associated economic analysis is sensitive to the capacity and timing for new generation investment in the upper North Island, as this local generation reduces the benefits of new transmission augmentation. Figure 3.1 illustrates the cumulative total of local generation included in the Auckland and North Isthmus region for each scenario.

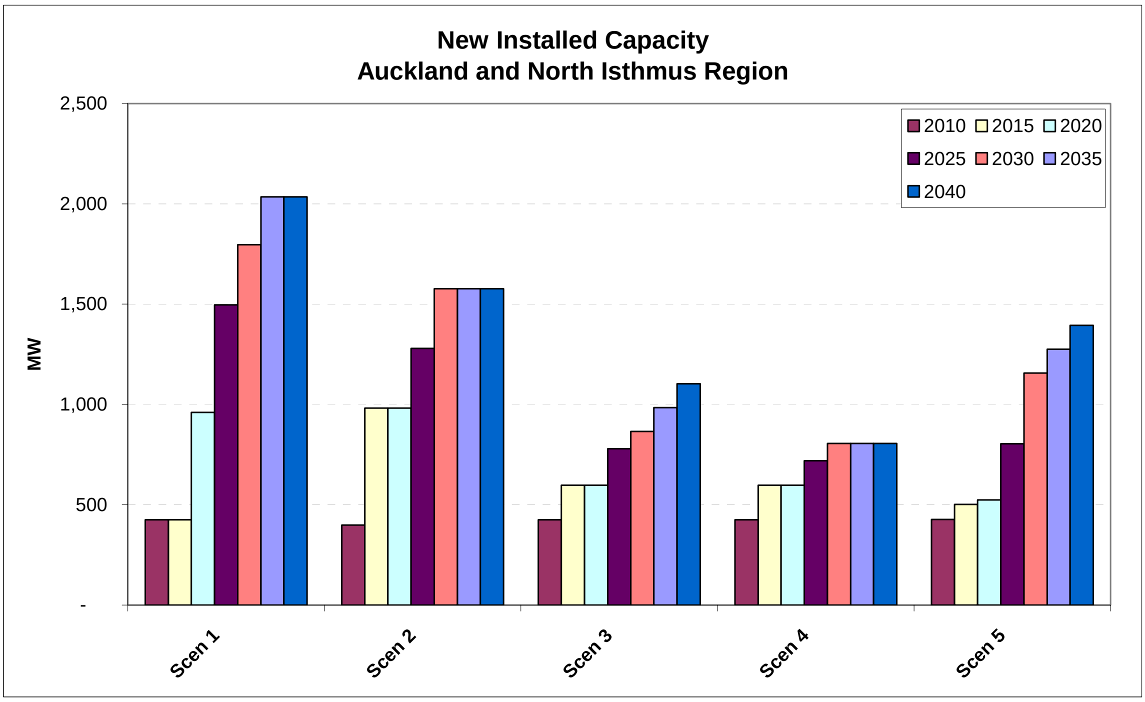

Figure 3-1: Upper North Island New Installed Generation Capacity per Scenario – Transpower version

Further information on the forecast generation for each grid exit point under each scenario can be found in the Transpower document: "North Island 400 kV Project Planning Assumptions – Demand and Generation Forecasting".

3.2 Comparison with Electricity Commission's Generation Scenarios

While broadly consistent in terms of scenario type, the generation scenarios used by Transpower contain some differences to those that have been recently published for consultation by the Electricity Commission in their Statement of Opportunities.

The amount of local generation included in each of the Electricity Commission's scenarios is set out in Figure 3.2. The comparison shows that Transpower's scenarios all contain more generation in the upper North Island than scenarios published by the Electricity Commission. Transpower's scenarios therefore provide a harder economic test for the proposed 400 kV line between Whakamaru and Otahuhu. This is because any generation north of Auckland relieves (or delays) the requirement for transmission reinforcement from the south. Transpower's scenarios therefore provide for less unserved energy[1] forecast in the economic analysis.

Transpower therefore considers that the differences between the scenarios used for this analysis and those published by the EC for consultation are not material to the outcomes of the economic analysis set out in Part IV.

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[1] The key benefit of new transmission augmentation in the National Benefit test methodology is the avoidance of unserved energy, valued at $20,000 MWh.

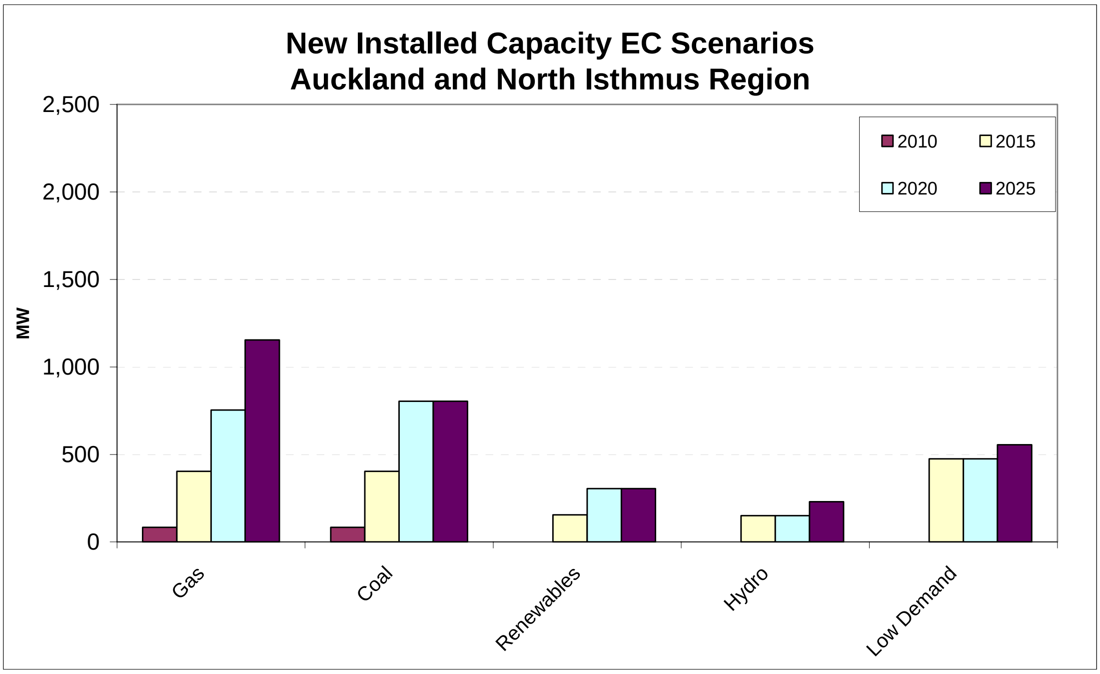

Figure 3-2: Upper North Island New Installed Generation Capacity per Scenario - Electricity Commission Version

4 Grid Reliability Standards

Transpower's current grid reliability standards form the basis of its transmission planning criteria. Transpower uses the criteria to justify the requirement for a new transmission investment from a planning perspective.

Under Transpower's transmission planning criteria, the main interconnected transmission system supplying upper North Island regions is designed to maintain an N-1 security criterion, meaning that the system is in a secure state with all transmission facilities in service and in a satisfactory state following a single contingency. These standards are consistent with the real time standards for system operation applied by the system operator under Part C of the Electricity Governance Regulations.

The single contingencies considered under the N-1 criterion are:

- loss of a single transmission circuit
- loss of a single generating unit
- loss of a single bus section (for new transmission builds only)
- loss of an interconnecting transformer
- loss of a single reactive component, e.g. capacitor bank or SVC

Transpower's current transmission planning criteria are consistent with the new Grid Reliability Standards (GRS) that were published by the Electricity Commission in May 2005.

A copy of Transpower's transmission planning criteria, against which the proposed investment is analysed, is available in the document titled "North Island 400 kV Project – Main Transmission System Planning Criteria.

5 Existing and Proposed Power System

5.1 Existing Generation within the upper North Island

The generation that can be assumed to be reasonably available within the region is determined by two factors:

- The installed capacity of the generation
- The availability of the generation plant for dispatch

For the purposes of determining system adequacy, only the existing and committed generation plant in the region have been considered. The plants' availability is affected by two factors:

- reliability of the generation plants leading to plant capacity reduction due to the unplanned outages and
- the operating restrictions on the plants due to availability of the fuel resources and/or the constraints placed on the operation of the plants.

5.1.1 Capacity of the Generation Plant

Electricity generation in the North Island is a mix of thermal power from Huntly, Stratford and Otahuhu power stations, hydro power from the Waikato River and central North Island stations and geothermal power from Wairakei, Ohaaki and Mokai stations.

The combined installed generation capacity in the upper North Island is 1947 MW. A break down of this figure is given in Table 5-1.

Generating Station	Installed Capacity MW
Glenbrook[2]	55
Otahuhu CC	365
Southdown	122
Huntly[3]	1405
TOTAL	**1947**

Table 5-1: Generation in Upper North Island Regions

Generation from Huntly in the table includes the existing coal/gas fired steam generation plant of capacity 4x250 MW, the gas turbine plant (P40) of capacity 1x40 MW and the

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[2] For cogeneration plants, the average monthly dispatch is assumed

[3] Generation from power plants at Huntly is included in the table above because, while it is located in the Waikato region, its relative proximity to the Auckland region (compared to generation near Whakamaru), means that it does have an effect on supply security.

new generation (e3p) presently being built by Genesis, of estimated capacity 1x365 MW. It is expected that the new gas fired single shaft combined cycle generation plant will be in service by 2007.

Transpower is aware that at least two other significant generation projects have been suggested, by Contact and Mighty River Power at Otahuhu and Marsden Point respectively. These projects have not been reflected in the assessment of the adequacy of the existing system as they are still some way from being committed or confirmed. However generation to this effect has been included in all of Transpower's generation scenarios so the impact of this plant on the economics of the proposed investment has been considered.

5.1.2 Availability of the Generation Plant

The supply security of the regional load is dependent on two critical factors, reliability of the generation in the area and the secure transmission capacity into the region. By 2010, all the major generating plants available in the region will be thermal plants. The largest units will be the single shaft, single generating unit, combined cycle generating plants at Otahuhu and Huntly (exceeding 350 MW/unit) followed by the four gas/coal fired steam units at Huntly (250 MW/unit). Such thermal plant has a substantially lower level of availability and reliability than transmission equipment. Therefore an assessment has been completed on the likely level of actual generation that can be reasonably and prudently assumed to be available.

Historically, a failure of one of the major plant items (e.g. unit transformers or boilers) results in a long repair time. Assuming the average failure rates of the similar machines reported in international literature, the assessed plant availability in the region (including Huntly) is shown in Figure 5-1. Detail of the assessment of generator availability is described separately in the report: "North Island 400 kV Project – Monte Carlo Analysis of Auckland Area Thermal Plant Availability"".

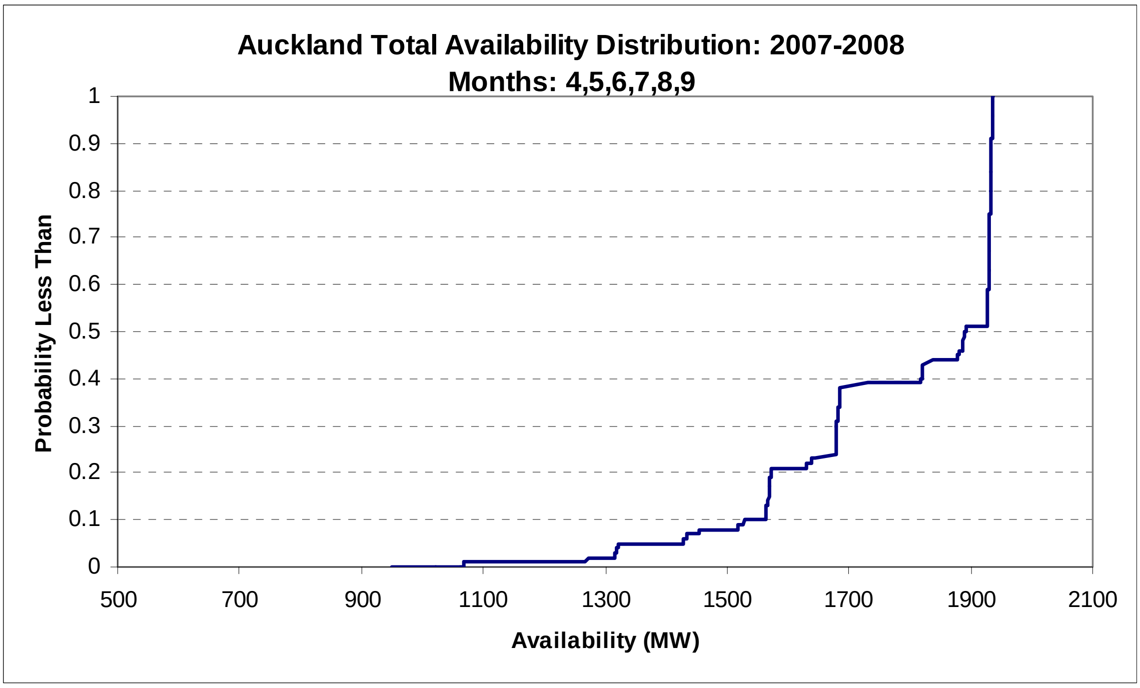

Figure 5-1: Cumulative probability of the availability of generation in the Auckland area between April and September being less than a given maximum generation

The figure shows that of 1947 MW total installed capacity, the actual amount of generation that can be expected to be available in the region is likely to be less than 1500 MW for approximately 10% of the time due to forced outages. Similarly, generation is likely to be less than 1600 W for approximately 20% of the time.

Because the unavailability of synchronous condensers has not been taken into account, the availability of generating stations and the synchronous condensers (when considered together) to provide the reactive support required by the region will be even smaller than the availability of the generating plant considered alone.

A reasonable and prudent system planning process must take into account the fact that thermal generation cannot always be available for injection into the grid. Therefore, the unavailability of a major generating plant in the region during and following any single credible contingency event has been taken into consideration in assessing the transmission capability into the region.

5.2 Existing North Island Transmission Grid

The North Island grid includes a number of core 220 kV circuits, and the HVDC bi-pole link linking the South and North Islands. Power transfer is normally from south to north.

The transmission system used for the analysis is the network as at 1 January 2005, together with the projects identified as “committed” as outlined in the Transpower publication “Future of the National Grid – Transmission Plan Summary (December 2004).”

During various outages, the transmission capacity of the grid to supply power to North Island regional loads may be subject to practical limitations. The major factors limiting power transfer capability are thermal capacity, voltage instability, and transient instability due to heavy circuit loading and distances between generation and load. Further details of existing transmission limits which affect transmission capacity are available in Transpower’s System Security Forecast as published in December 2004.

5.2.1 Auckland Regional Transmission System

Figure 5-2 shows a schematic representation of the transmission grid supplying the upper North Island regions.

The Auckland region is supplied mainly over a number of 220 kV and 110 kV lines from the Waikato region to the south, including:

- the double circuit 220 kV Stratford-Taumarunui-Huntly-Otahuhu line,
- the double circuit 220 kV Whakamaru-Otahuhu C line,
- the single circuit 220 kV Whakamaru-Otahuhu A&B lines.
- the double circuit 110 kV Arapuni-Hamilton-Bombay-Otahuhu line, and
- the double circuit 110 kV Arapuni-Pakuranga line[4]

The region north of Auckland is supplied from Otahuhu via the following 220 kV circuits:

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[4] Presently the two circuits are bonded and operated as a single circuit. Transpower intends removing this line from service as part of this proposed investment.

- the double circuit 220 kV Otahuhu-Henderson line (with one circuit passing through Southdown)
- the double circuit 220 kV Henderson-Marsden A line

The planned and committed transmission upgrades, which have a significant impact on transmitting power to the upper North Island region are summarised in Table 5-2.

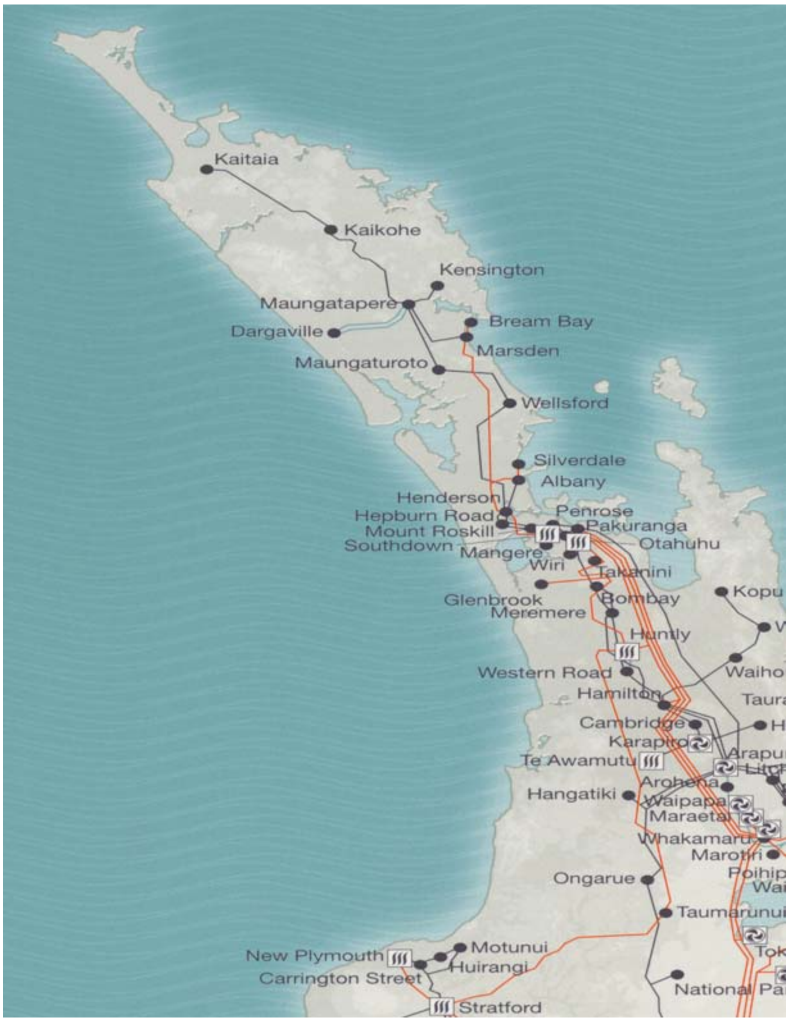

Figure 5-2: The Upper North Island Region and Transmission Schematic

Grid Upgrade Project	Post Upgrade Capacity	In-Service Date
Thermal upgrade of 220 kV Otahuhu – Penrose circuits 5&6	469/492 MVA (Sum/Win)	2006
Thermal upgrade of 220 kV Huntly – Otahuhu circuit 1	614/671 MVA (Sum/Win)	Completed
2 x 50 MVAr 110 kV shunt capacitors at Penrose substation	50 Mvar (1x 50 Mvar is a replacement unit)	2006
1 x 50 MVAr 110 kV shunt capacitor at Hepburn Road sub station	50 MVAr	2006
Thermal upgrade of 110 kV Bombay - Otahuhu circuits 1 & 2	92/101 MVA (Sum/Win)	2005

Table 5-2– Committed tactical transmission upgrades assumed in the system adequacy analysis

5.2.2 Voltage Support in the Auckland Region

Presently, there is a total reactive capacity of 630 Mvar connected to the grid and approximately an additional 240 Mvar of capacity connected to the distribution substations in the Auckland region.[5] While the capacitors connected to the distribution substations improve the power factor of the connected load to approximately 0.975, the capacitors connected to the transmission system are mainly used for compensating the reactive power loss in the transmission circuits. At present, two of the Otahuhu synchronous condensers have been contracted to provide 2x33 Mvar dynamic reactive support in addition to the grid connected capacitors.

In order to maintain voltage stability in the region up until 2010, the following additional reactive power support set out in Table 5-3 (in addition to that outlined in Table 5-2) is required to be available during the period 2006-2010.

Location	Capacity	Year
Otahuhu (Synchronous Condensers)	1x33 + 2x50 Mvar	2006
Marsden (Synchronous Condensers)	1x80 Mvar	2006
Otahuhu (Capacitor Bank)	1x100 Mvar	2009
Albany (Static Var Compensator)	+/- 100 Mvar	2008

Table 5-3: Additional Static and Dynamic Voltage Support Anticipated in the Region Prior to 2010

5.2.3 Further Grid Augmentation within the Greater Auckland Area

Transpower has developed tentative plans for long range development of the core grid in the greater Auckland area to ensure that the required level of reliability will be maintained for conveying the additional power delivered from Otahuhu to grid exit points in Auckland and north beyond 2010.

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[5] A list of grid connected capacitors in the upper North Island regions is provided in Appendix II-B

These developments mainly involve reinforcement of connections from Otahuhu to Penrose, from Otahuhu to Mt Roskill, from Otahuhu to Pakuranga and from Otahuhu to Henderson at 220 kV and are shown schematically in Appendix II-C.

This submission does not include a request for approval of expenditure on these further developments as grid reliability investments. This will be the subject of a separate submission.

6 Assessment of Transmission Capability

6.1 Introduction

This Section details the analysis undertaken by Transpower to assess the adequacy of the upper North Island transmission system. Transpower assessed the capability of the transmission system in terms of its ability to meet the forecast demands and remain within the current grid reliability standards for a range of credible power system contingencies specified in those standards. A key issue highlighted in this analysis is that there is no single absolute system limitation. Transmission system limitations are dependent primarily on generation and transmission equipment availability. Therefore, the system limits into Auckland will vary substantially throughout the year as equipment (particularly generation plant) is made unavailable for a range of reasons whether they are planned or unplanned outages, due to market conditions or weather (hydrological) conditions.

6.2 Methodology

In order to capture the wide range of potential power system conditions and their associated impact on system adequacy, sensitivity analysis was performed to test the robustness of the power system to sustain satisfactory operating conditions under a range of events that can be reasonably expected to occur.

A large number of power system analysis studies were completed to identify the limitations on power supply into the Auckland area including:

- Power flow analysis to identify thermal limits into the region, i.e. the point at which assets may become overloaded due to contingent events on the system.
- Voltage stability analysis to identify voltage collapse limits into the region, i.e. the point at which the upper North Island regions are at risk of voltage collapse and consequential total or partial loss of supply to the upper North Island regions.
- Transient stability analysis to identify stability limits into the region, i.e. the point at which sections of the power system separate from the bulk of the national grid system leading to cascade failure of that section of the power system supplying the upper North Island regions.

The following potential transmission system limitations may come into play:

- Thermal Limitations

- Voltage Stability Limitations
- Transient (Angle) Stability Limitations

6.3 Power Flow Analysis

All power system equipment has thermal limitations which are set by the physical design of plant. Cascade failure due to thermal overload may occur when overloaded equipment fails, placing a higher burden on the remaining in-service equipment, which may then continue to fail in a cascade fashion.

The thermal capacities of the relevant 220 kV transmission circuits are set out in Table 6-1[6].

Circuit	Summer Rating (MVA)	Winter Rating (MVA)
Otahuhu-Whakamaru-1&2	202	246
Otahuhu-Whakamaru-3	403	491
Hamilton-Whakamaru 1	403	491
Hamilton-Huntly 1	403	491
Huntly-Otahuhu 1[7]	614	671
Huntly-Otahuhu 2	694	764
Glenbrook-Huntly 1 and Glenbrook-Otahuhu 1	694	764

Table 6-1: Thermal Ratings of the 220 kV circuits supplying the Upper North Island

Under normal operating conditions (i.e. when the inter-island power flow is from south to north), the Otahuhu - Whakamaru circuits transfer power generated in the central North Island hydro and geothermal stations as well as a proportion of hydro power generated in the South Island, into Auckland and further north. In contrast, the Huntly-Otahuhu circuits are mainly used for transferring the power generated from the thermal power stations in Huntly and Stratford.

The power that reaches Otahuhu via all the existing 220 kV circuits is transferred within the region and northwards through a network of 220 kV and 110 kV circuits. While some of the circuits used for transferring power further north are heavily loaded (e.g. Otahuhu – Henderson circuits), they do not have a direct bearing on the thermal loading of the transmission circuits transferring power to the region from the south.

The actual thermal loading of the circuits supplying Auckland is dependent on the demand in the region, local generation and the availability of the transmission circuits (i.e. having anticipated any unplanned outages). In particular, in determining the thermal limitations, the consideration of security of supply to loads under the following conditions is important:

- The limitations during the outage of one transmission circuit when a reasonable level of generation is not available in the Auckland region itself. Any deficiency of

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[6] There are different thermal limits for summer and winter operation recognising the effect of ambient temperature on the actual operating temperature of the conductors

[7] Thermal upgrading of the Huntly – Otahuhu section of Otahuhu – Whakamaru C line in 2005 April has increased the line rating from 402/492 MVA to 614/671 MVA.

generation within the region needs to be met with transmission from the south and therefore the loading of the transmission circuits will increase.

- The limitations during the outage of one transmission circuit when a reasonable level of generation is not available from Huntly. Any deficiency of generation from Huntly, which would have transferred to the Auckland region via the Huntly-Otahuhu circuits, now needs to be met using transmission from Whakamaru to Otahuhu. Consequently there is an increase in the loading of the Otahuhu-Whakamaru circuits.

The generation available in the immediate Auckland area amounts to approximately 540 MW from three stations, including a single shaft combined cycle power station of capacity 365 MW in Otahuhu. By 2010, the generation available from Huntly will amount to approximately 1400 MW, including the generation from the combined cycle e3p power station of 365 MW. Consequently, the existing transmission circuits need to provide sufficient thermal capacity for supplying the upper North Island when a generating station such as Otahuhu B or a large generating unit at Huntly is out of service for planned or unplanned outages. (Note: planned outages involving extensive maintenance and unplanned outages due to plant failure could last from several hours to several months).

Figure 6-1 and Figure 6-2 illustrate the relationship between generation injection from Huntly and the loading on the Otahuhu-Whakamaru circuits 1 and 2 and the Huntly – Otahuhu circuit 1, to be expected by 2010 winter and summer respectively. An increase in generation from Huntly increases the thermal loading of Huntly-Otahuhu circuit 1 and reduces the loadings on Otahuhu-Whakamaru circuits 1 and 2 for the worst case N-1 contingent events. These are Otahuhu-Whakamaru circuit 3 outage for Otahuhu-Whakamaru 1 and 2 overloading and Huntly – Takanini – Otahuhu for the Huntly – Otahuhu circuit 1 overloading.

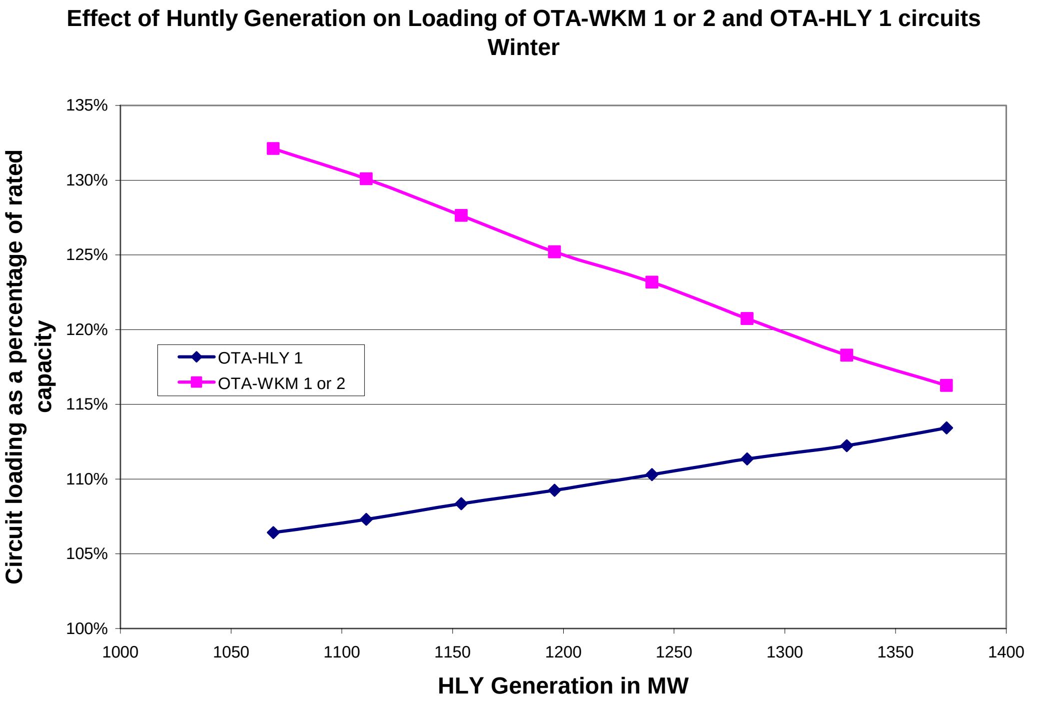


Figure 6-1: Relationship between Huntly generation and loading of Huntly-Otahuhu and Whakamaru –Otahuhu circuits (Winter power flow).

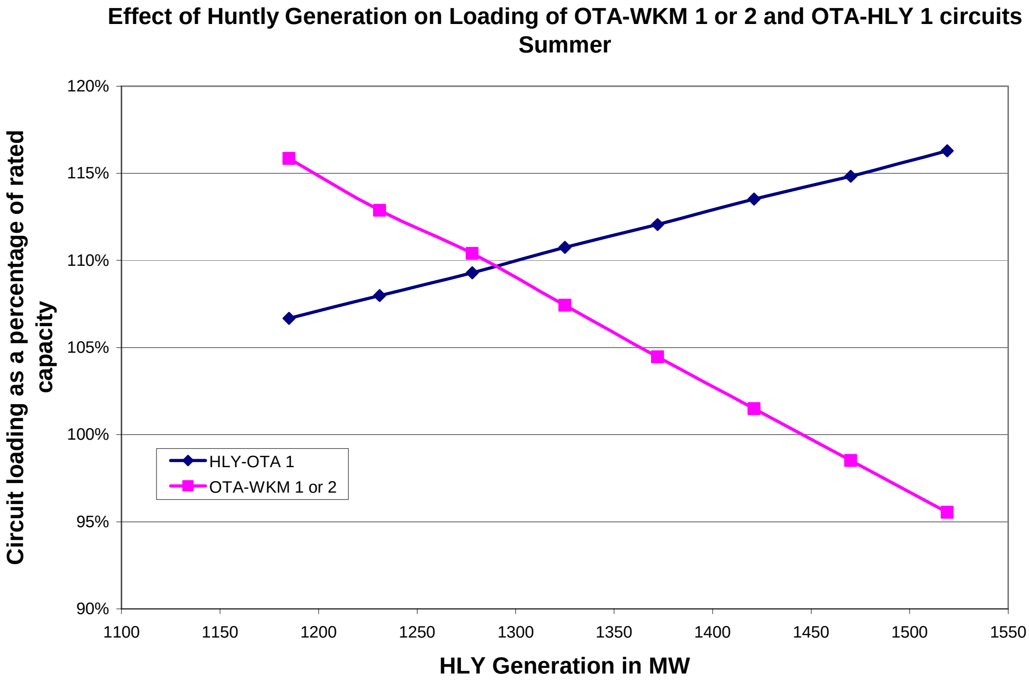


Figure 6-2: Relationship between Huntly generation and loading of Huntly-Otahuhu and Whakamaru –Otahuhu circuits (Summer power flow).

It is clear from the above results that the thermal limitations on the major 220 kV circuits supplying Auckland is a concern by 2010, especially if any major generation in Auckland is out of service during peak load times. The Otahuhu – Whakamaru circuits 1 and 2 may be able to be to be thermally upgraded to provide a modest increase in thermal capacity, however detailed investigations to determine how much additional capacity can be extracted are not yet complete. The Huntly – Otahuhu circuits have recently been thermally upgraded, therefore, the thermal capacity of these particular lines is already at its maximum point.

6.4 Voltage Stability Analysis

The maximum power that can be transferred over a transmission link may also be limited by the voltage stability performance of the system.

Voltage instability is a known mode of cascade failure of power systems. Voltage stability analysis has been completed to determine maximum power transfer limits for transmission planning. The methodology and the results are set out in this section.

The power transfer limit into Auckland for voltage stability is dependent on a number of factors namely:

- The impedance of the transmission system including lines and transformers.
- The quantity of demand supplied, including its power factor.
- The real and reactive power capability of generation connected to the power system particularly in (or near) Auckland.
- The reactive power compensation (static and dynamic) available in the region

The voltage stability analysis has been completed in two stages. The first being "static" analysis which provides a view of how the system will perform in the absence of external disturbances. The second being "dynamic" analysis which models how the system will behave in response to disturbances such as faults on the transmission grid.

It is important to model both static and dynamic behaviour of the power system as this provides a more thorough test of potential system conditions that may lead to total or partial failure of supply. The voltage stability limit is determined by the lesser of the two limits resulting from this analysis. Dynamic analysis is widely considered to be more relevant as it provides simulations of the expected behaviour of the power system over a period of time rather than a single "snapshot" as provided by static analysis. Dynamic analysis generally delivers lower power transfer limits than static analysis.

6.4.1 Static Analysis

Static analysis has been performed to provide a snapshot of the system conditions that occur at or near the point of voltage collapse and to indicate what measures might be adopted to avoid operation of the transmission grid at or near the point of voltage collapse.

The results of the static analysis illustrated in Figure 6-3 show that the steady state limit can be increased up to a practical limit by the installation of increasing amounts of static capacitors. However, the effectiveness of the additional capacitors decreases as the total extent of the capacitors installed increases to a point where further capacitors have no material effect.

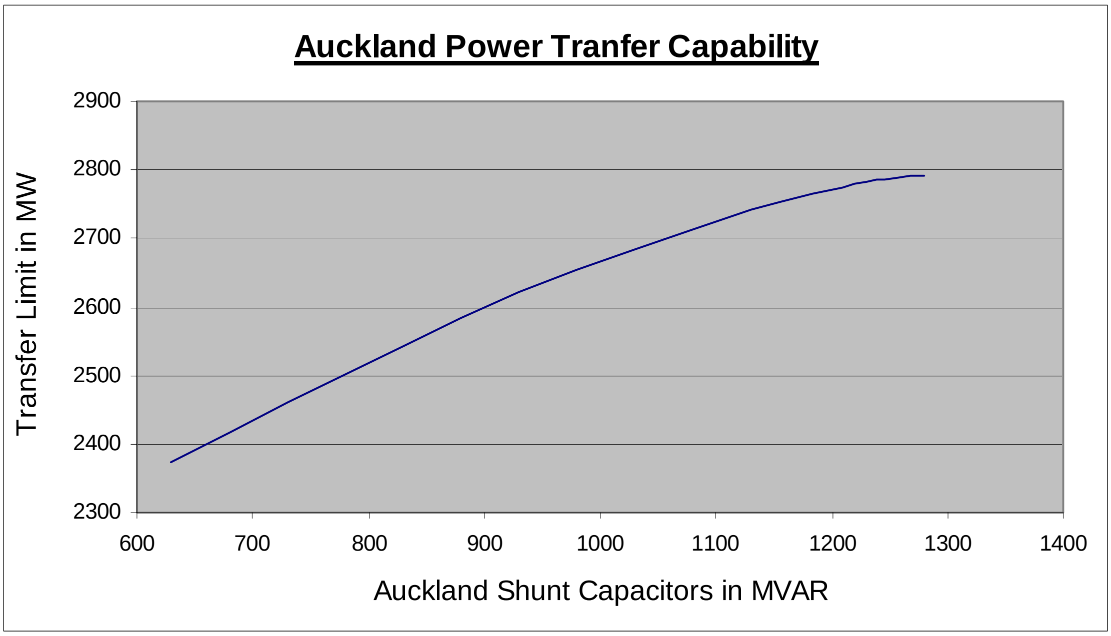


Figure 6-3: Variation of the maximum power transfer limit with grid connected reactive compensation.

6.4.2 Dynamic Analysis

Dynamic analysis was performed to analyse the performance of the power system over time, in particular how the power system would respond to simulated events or disturbances such as transmission faults. These "dynamic voltage stability limits" depend on the dynamic performance of a power system which has many uncertainties, and hence the voltage stability limits can be nothing more than informed estimates.

A detailed discussion of the factors involved in the estimation of dynamic voltage stability limits is set out in Appendix II-D attached.

The dynamic voltage stability limit for supplying the upper North island demand through the core grid is critically dependent on the generation as well as on the reactive power compensation, locally available within the region.

The amount of local generation that is installed and operating at any particular time in upper North Island is doubly significant in the estimation of the dynamic voltage stability limits for the supply of power over the core grid to the south of Auckland. If generating plant is out of service, the available quantum of local power will be reduced requiring additional power to be imported over the heavily loaded transmission grid and, in addition, the region will be deprived of an important source of dynamic reactive power support.

Figure 6-4 below illustrates the effects of the availability of local generation and reactive power support (dynamic and static) in the estimation of the dynamic voltage stability limit for the core grid supplying the upper North Island from the south.

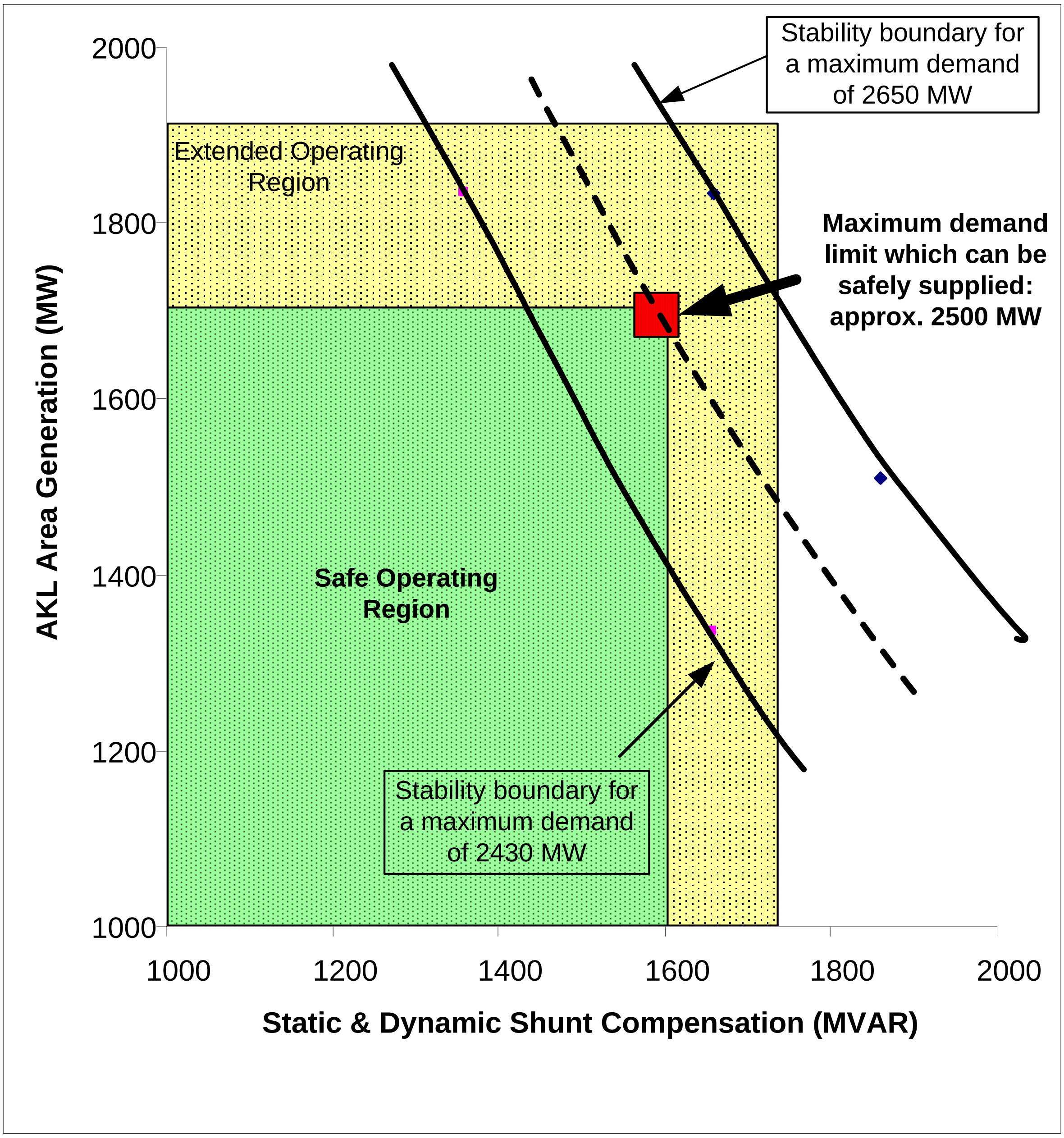


Figure 6-4: Estimation of the Dynamic Voltage Stability Limit for the Core Grid Supplying the upper North Island from the South

The figure shows that the dynamic voltage stability limit depends upon the extent of local generation operating in the upper North Island and the extent of reactive voltage support installed in the Auckland area.

The extent of local generation is limited by the capacity of the plant that is installed and serviceable at any particular time. The maximum extent of the reactive power support (static and dynamic) that can be usefully installed in the Auckland area is limited by the potential onset of cascading voltage collapse near the dynamic voltage stability limit for the grid. The installation of further reactive voltage support will reduce the voltage controllability of the power system even if the reactive power support is in the form of static var compensators (SVC's).

As discussed, heavy reactive compensation of the power system is not desirable due to operating inflexibility. Section 5.1 shows that no more than 1700 MW of generation in the upper North Island regions (including Huntly) can be reasonably assumed to be available more than 60% of the time.

Table 6-2 demonstrates the sensitivity of the controllers, when the region is heavily shunt compensated. The results show that a slight variation of the reactive power output from the dynamic reactive power sources (e.g. generators) needs to be compensated by a large quantity of static reactive sources (i.e. capacitor banks) in order to maintain the system stability.

Auckland plus Northern Isthmus load level (MW)	OTC generator initial output (MVAR)	VAR compensation required in Auckland area for loss of OTC (MVAR)	
		Dynamic (SVC + synchronous condensers)	Static shunt capacitors
2640	0	390	1270
2640	-40 (i.e. absorbs VARS)	390	1070

Table 6-2: Reactive power requirements of heavily shunt compensated Auckland system. (Negative Vars represent that the generator is operating at a leading power factor)

The above example confirms that, while the transmission system is capable of supplying the Auckland and North Isthmus demand up to approximately 2650 MW with very heavy shunt reactive compensation in the region (note: total dynamic and static reactive compensation required in the above example is approximately 1500 – 1700 MVAr), the power system operation becomes very sensitive to the reactive power variations. Such increased sensitivity to reactive or real power variations is a clear indication of the power system operation nearing the unstable operation region. Therefore, operating the power system with increased level of reactive compensation above approximately 1500 – 1600 MVAr can not be considered to be prudent and would carry with it significant operational risk of cascade failure.

The figure shows that while it is theoretically possible to supply a total demand of 2650 MW in the upper North Island regions, this would require:

- the acceptance of significant risks in relation to the quantum of generating plant actually operating in the region;
- an extremely high level of reactive voltage support; and
- an inherently high risk of cascading voltage collapse.

The above figure shows that taking this into account and making due allowance for the uncertainties in the estimation of the dynamic voltage stability limit, a upper North island load of 2500 MW would be approximately the maximum load that can be securely supplied using the existing grid assets (including the transmission upgrades and reactive power support planned to be installed prior to 2010). It should be noted that in the real time operation of the power system, the system operator would subtract a stability margin off this figure such that the system was not operated right up to the point of possible voltage collapse. This margin is 5% of the total demand.

6.4.3 Transient Stability Analysis

Another limitation to power transmission is the ability to operate the synchronous machines (generators as well as motors), in the sending system and the receiving system, in synchronism under all the operating conditions and to survive a credible contingency event. As described in Section 5.1, there is some local generation in the Auckland region itself and the remaining regional load has to be supplied from the generation at Huntly, and Waikato and Taranaki regions.

Transient stability is significantly influenced by the electrical characteristics of the transmission system between the sending and the receiving regions. Simulation studies have shown that, a large amount of generation can not be transferred to the Auckland region from the south (e.g. from Taranaki) due to the electrical characteristics of the transmission paths, Taranaki - Huntly-Auckland and Taranaki - Bunnythorpe - Whakamaru - Auckland.

Figure 6-5 shows the large disturbance instability of the power system following a three phase fault at Stratford 220 kV bus and cleared by opening a Stratford to Huntly circuit.

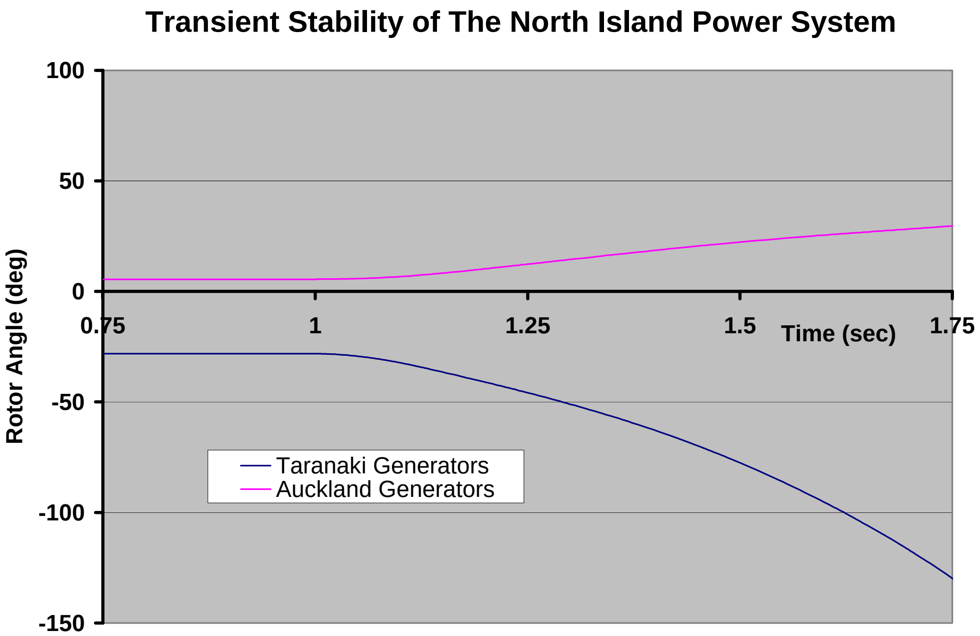


Figure 6-5: Loss of transient stability between Taranaki and Auckland generation

The figure shows that following a fault on a Stratford to Huntly circuit, the generators in Taranaki region would lose synchronism with respect to the generators in the Auckland region, under an operating condition with high Taranaki generation and the load in the Auckland region about 2500 MW.

This instability will pose a significant constraint for transferring power from Taranaki to Auckland and is significantly influenced by the transmission impedance of the SFD-HLY lines. Because of this constraint, during an outage of a generating unit in the Auckland area, significant generation from Taranaki could not be transferred to Auckland without taking an unacceptable risk of a cascading shut-down of the upper North Island. The constraint upon Stratford generation means that additional generation would have to be made up from the generation from Huntly, Waikato, the central North Island and (if possible) increasing the power transfer from the South Island over the HVDC. Make up power from all or any of these sources conspire to increasing the loading the Whakamaru to Otahuhu lines thus pushing the upper North Island region closer to its thermal overload and dynamic voltage stability limits.

7 Timing of Grid Augmentation

Section 6 detailed how the transmission capacity of the existing transmission system (including committed and anticipated grid augmentation) can be limited by the thermal capacity, voltage stability or the transient stability of the transmission system. While, at present, the transmission system is operated close to these stability and capacity limits, the increasing demand in the upper North Island region will cause a rapidly escalating risk of a cascade failure of supply.

The voltage stability limit is dependent on the local generation available in the region (including the generation from Huntly) and the level of reactive power compensation in the region. While increasing the reactive compensation in the region can further increase the transmission capacity, this is achieved only through greater economic costs and significant technical risks. Further, the reliability of the thermal generating units in the region is such that it can not reasonably be assumed that more than approximately 1700 MW generation will be available on a sustainable basis in the region by 2010.

The analysis summarised in the form of Figure 6-4 demonstrated that the maximum demand for the upper North Island regions that can be reliably and securely met without major augmentation of the grid is approximately 2500MW, which is the point at which voltage collapse of the system was modelled...

Figure 7-1 shows the peak demand forecast of the Auckland region overlaid with this transmission limit. (The demand shown in the figure represents the actual demand that can be safely supplied from the grid allowing for a stability margin of 5%). The existing transmission system with increased level of reactive power compensation and significant constraints on the operation of the generators (in order to manage the associated operational risks) is just adequate for supplying the medium forecast load until 2010.

System Adequacy Under Low, Medium and High Load Growth Scenarios

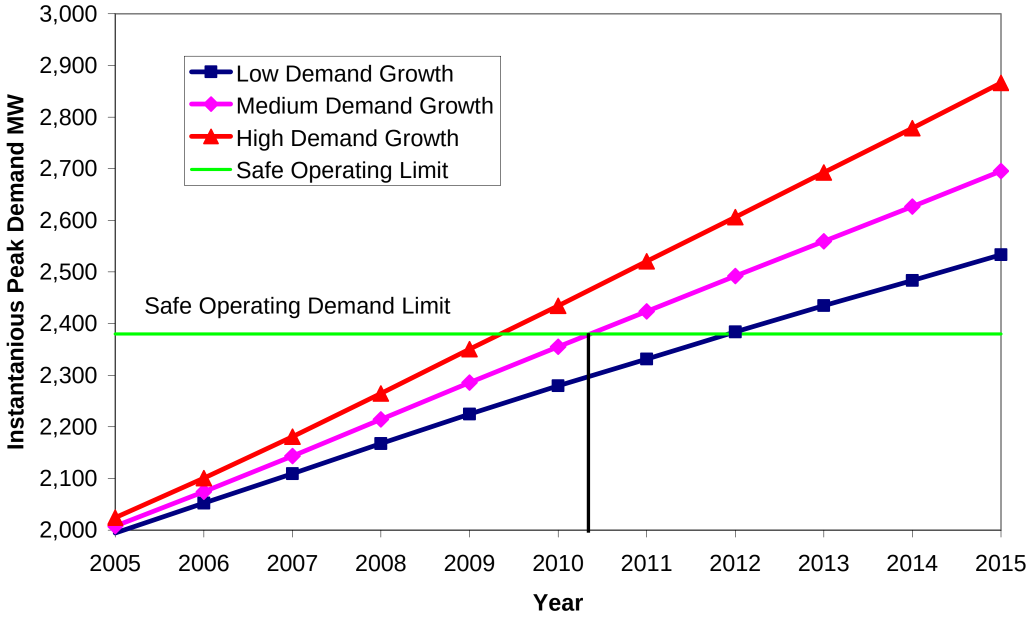


Figure 7-1 System Adequacy for supplying the upper North Island load.

The figure also shows that under a high demand growth scenario, the capacity of the existing transmission grid for supplying the upper North Island demand is only adequate up to 2008. Under such a scenario, it would be difficult to meet the 2009 -2010 demand without taking significant operating risks. Under a low growth scenario, supply security to the Auckland region can be provided until approximately 2012.

Appendix II-A: Forecast of Upper North Island Demands

Forecast Upper North Island Half Hourly Average Maximum Demands						
	Average Half Hour ADMD Forecast			***Instantaneous Peak ADMD Forecast***		
Year	***Low(MW)***	***Medium (MW)***	***High (MW)***	***Low(MW)***	***Medium (MW)***	***High (MW)***
2005	1,904	1,918	1,934	1,994	2,008	2,024
2006	1,962	1,984	2,011	2,052	2,074	2,101
2007	2,019	2,053	2,091	2,109	2,143	2,181
2008	2,078	2,124	2,175	2,168	2,214	2,265
2009	2,135	2,196	2,260	2,225	2,286	2,350
2010	2,190	2,265	2,345	2,280	2,355	2,435
2011	2,241	2,334	2,431	2,331	2,424	2,521
2012	2,294	2,402	2,516	2,384	2,492	2,606
2013	2,345	2,470	2,602	2,435	2,560	2,692
2014	2,394	2,537	2,689	2,484	2,627	2,779
2015	2,443	2,605	2,776	2,533	2,695	2,866
2016	2,494	2,674	2,863	2,584	2,764	2,953
2017	2,546	2,746	2,956	2,636	2,836	3,046
2018	2,597	2,818	3,046	2,687	2,908	3,136
2019	2,651	2,889	3,137	2,741	2,979	3,227
2020	2,701	2,960	3,232	2,791	3,050	3,322
2021	2,751	3,031	3,325	2,841	3,121	3,415
2022	2,801	3,102	3,421	2,891	3,192	3,511
2023	2,850	3,173	3,513	2,940	3,263	3,603
2024	2,896	3,243	3,611	2,986	3,333	3,701
2025	2,943	3,312	3,702	3,033	3,402	3,792
2026	2,988	3,382	3,797	3,078	3,472	3,887
2027	3,032	3,452	3,894	3,122	3,542	3,984
2028	3,080	3,522	3,985	3,170	3,612	4,075
2029	3,126	3,592	4,081	3,216	3,682	4,171
2030	3,172	3,663	4,175	3,262	3,753	4,265
2031	3,218	3,734	4,272	3,308	3,824	4,362
2032	3,263	3,806	4,372	3,353	3,896	4,462
2033	3,310	3,879	4,471	3,400	3,969	4,561
2034	3,352	3,953	4,578	3,442	4,043	4,668
2035	3,395	4,028	4,684	3,485	4,118	4,774
2036	3,442	4,105	4,788	3,532	4,195	4,878
2037	3,485	4,183	4,897	3,575	4,273	4,987
2038	3,527	4,263	5,014	3,617	4,353	5,104
2039	3,581	4,345	5,119	3,671	4,435	5,209
2040	3,632	4,428	5,240	3,722	4,518	5,330
2041	3,684	4,514	5,360	3,774	4,604	5,450
2042	3,737	4,601	5,489	3,827	4,691	5,579
2043	3,786	4,689	5,614	3,876	4,779	5,704
2044	3,838	4,778	5,740	3,928	4,868	5,830
2045	3,887	4,869	5,877	3,977	4,959	5,967

Appendix II-B: Network Connected Capacitor Banks in the Auckland Region

Substation	Voltage (kV)	Capacitor (MVAR)
Kaikohe	11	20
Albany	110	50
Albany	11	60
Henderson	11	60
Henderson	220	75
Otahuhu	220	100
Otahuhu	110	100
Otahuhu	11	90
Penrose	220	75
	Total	**630**

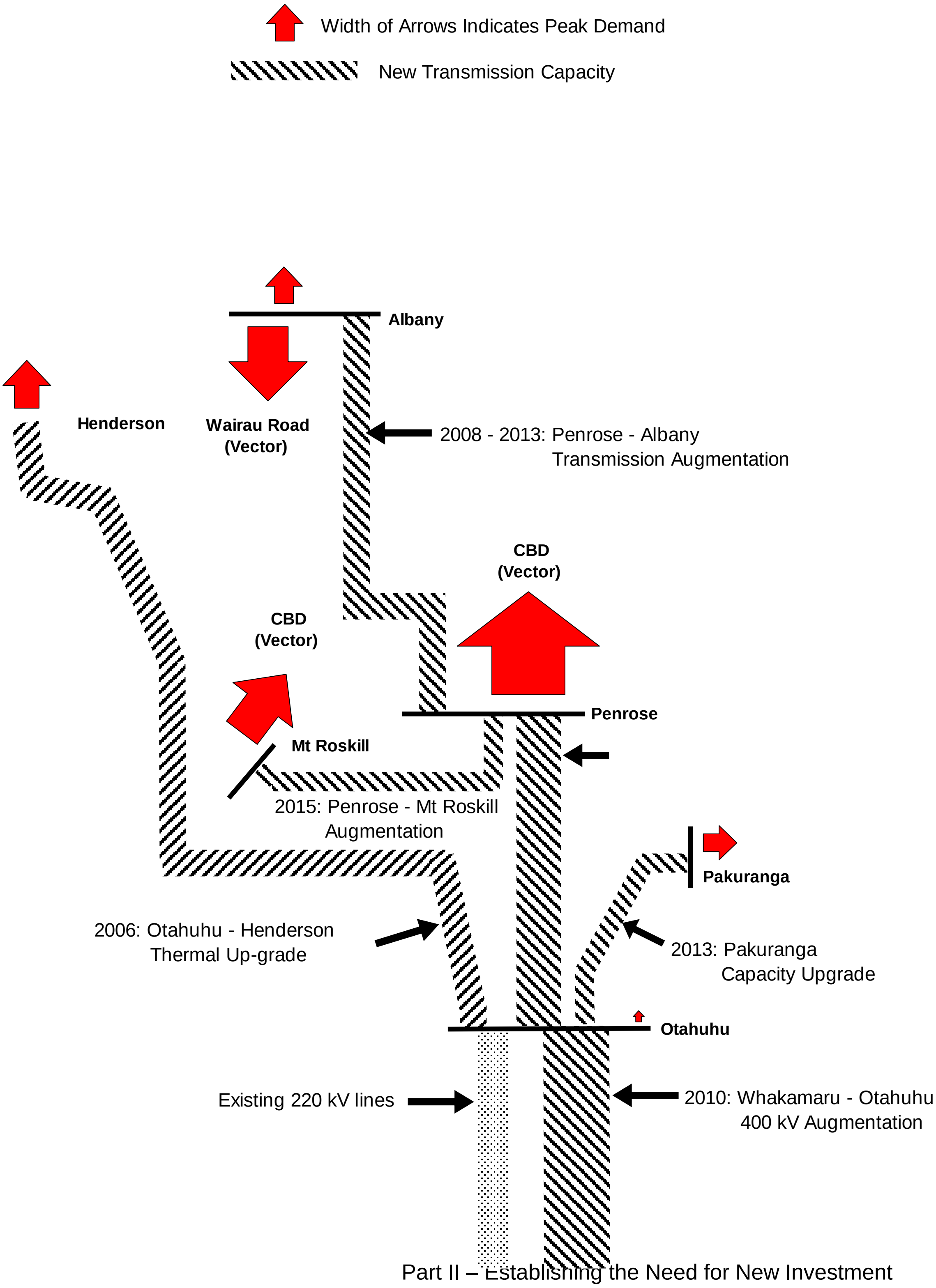
Table B-7-1: Capacitors connected at Transmission busses. 11 kV capacitors connected to tertiaries of interconnecting transformers

GXP	Voltage (kV)	Capacitor (MVAR)
Wairu Rd.	33	48
Albany	33	9
Dargaville	11	2
Henderson	33	12
Hepburn Rd.	33	22
Kensington	33	1
Mangere	33	3
Maungatapere	33	2
Maungaturoto	33	2
Otahuhu	22	9
Pakuranga	33	6
Penrose	33	66
Penrose	110	15
Mt Roskill	22	3
Mt Roskill	110	15
Takanini	33	6
Wellsford	33	6
Wiri	33	15
	Total	**240**

Table B-7-2: Distribution capacitors aggregated at their respective Grid Exit Points (GXP)

Appendix II-C: Anticipated Grid Reinforcement in the Greater Auckland Area

INTEGRATION OF AUCKLAND AREA DEVELOPMENT
WITH 400 kV GRID AUGMENTATION



Appendix II-D: Estimation of Dynamic Voltage Stability Limits

Power system voltage stability limits depend upon the variation of the system voltage during this period immediately following a disturbance. Generally, following a power system fault, the system voltage reduces momentarily and then recovers over a period of 1 – 3 seconds (Figure D-1).

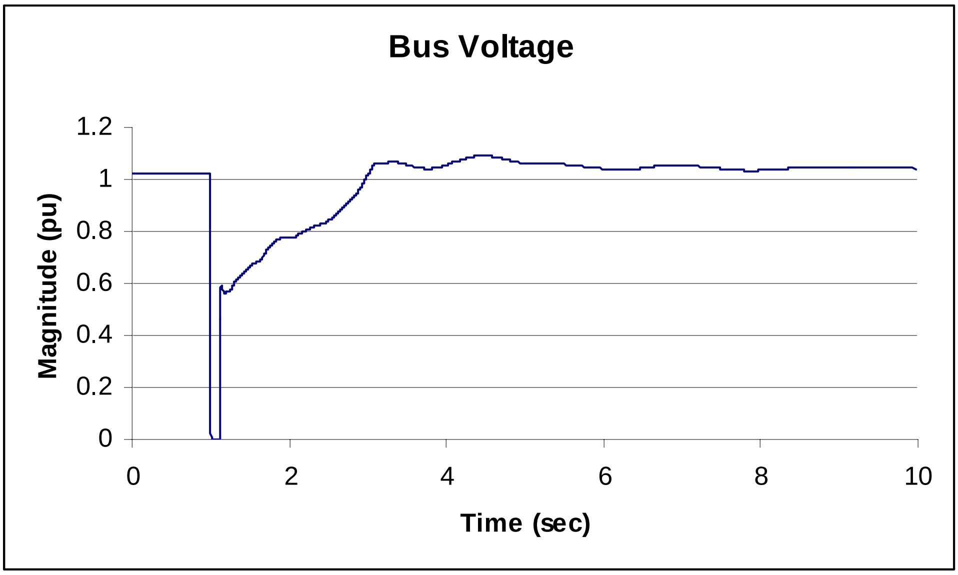


Figure D-1: Variation of the system voltage following a fault at Otahuhu 220 kV bus

The variation of the system voltage interacts with the connected loads and generators in the following manner during the transient period:

- The reduction of the system voltage contributes to the reduction in demand in three ways
  - (i). reduction in power consumed by the power output of the passive loads such as electrical lighting, heaters, etc
  - (ii). dropping off of the loads, especially the motor loads, as a result of magnetic contactor dropping off or due to the operation of protection relays
  - (iii). reduction in the power consumed by the motor loads which remain connected to the grid

- Reactive compensation provided by capacitors connected to the grid is proportional to the square of the system voltage. Hence, during transient voltage reductions, the reactive power compensation provided by the capacitors is significantly reduced resulting in a transient decrease in the overall power factor of the connected load.

  This decrease in load power factor contributes to a reduction in the dynamic voltage stability limit.

- The power output of the motors is proportional to the square of the system voltage Therefore at reduced voltages, the power output of the motor loads reduces, resulting in motors decelerating and in some instances stalling. The stalled motors and the motors which are operating at below their nominal speed consume a significant amount of reactive power and therefore decreases the overall power factor of the connected load. This decrease in load power factor contributes to reducing further the dynamic voltage stability limit.

- The generators, synchronous condensers and static var compensators (SVCs) increase reactive power output as a means of restoring the system voltage. This action effectively improves the power factor of the combined load at the receiving end. However, in estimating dynamic voltage stability limits, it is necessary to take into account that this plant will have physical limitations upon its ability to contribute to voltage support depending upon its installed capacity.

  The limitations upon this plant contribute to reducing further the dynamic voltage stability limit.

The typical performance of the power system components which have a significant impact on the estimation of the dynamic voltage stability limit of the power system are shown in the following figures D-2 and D-3. The figures show the variation of the reactive power compensation by the capacitors, reactive power consumed by the motor loads and reactive output of the generators, during the transient disturbance.

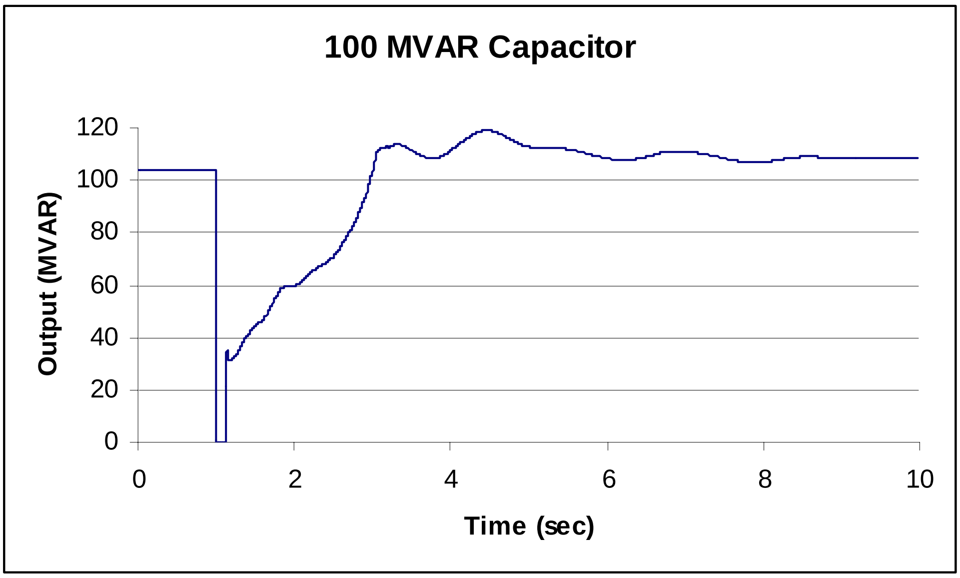


Figure D-2: Variation of reactive power compensation provided by a 100 MVAr capacitor bank at Otahuhu.

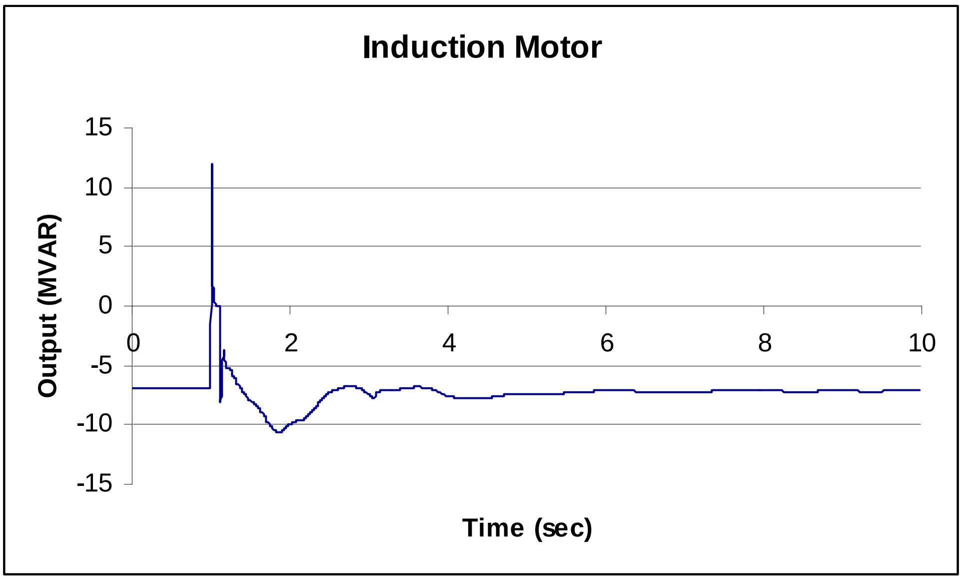


Figure D-3: Variation of reactive power consumed by a 20 MVA motor load. (note: reactive power consumed by the motor is shown as negative)

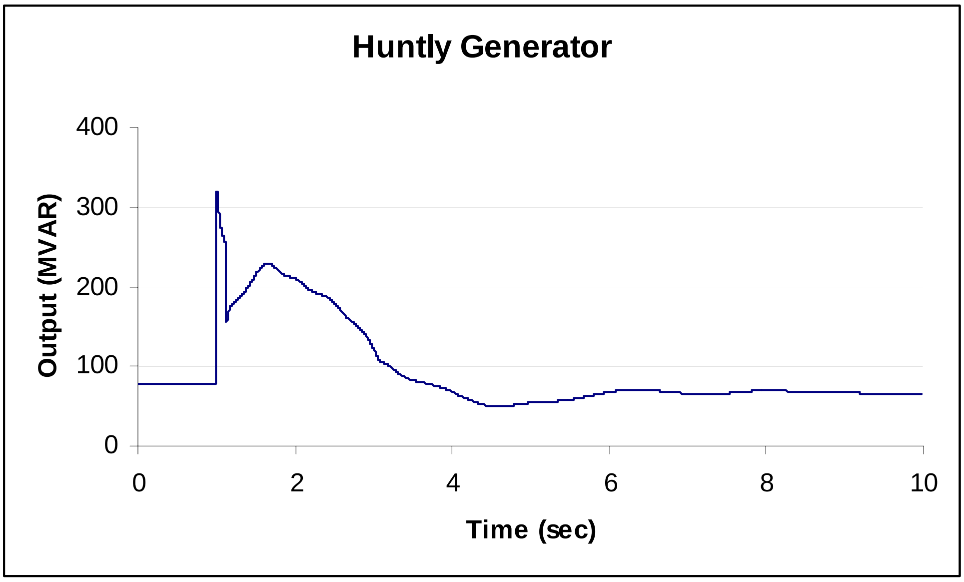


Figure D-4: Variation of reactive power output from a 250 MW generating unit at Huntly, operating at 100% power output.

As shown above, the performance of the power system and the connected loads following a power system disturbance is complex and its impact on the voltage stability is normally assessed by using simulation studies. In general, the power system performance during disturbances results in a <u>dynamic voltage stability limit</u> significantly less than that voltage stability limit that would be estimated using a simplistic static analysis.