



T R A N S P O W E R

**Transpower's North Island 400 kV
Grid Upgrade Investment
Proposal - Synopsis**

July 2005

1 Introduction

Transpower formally submitted its North Island 400 kV Grid Upgrade Investment Proposal on 31 May 2005, under the transitional provisions of Part F of the Electricity Governance Rules.

The key aspects of Transpower's submission and the structure for the rest of this document are given in the table below:

| Title | Outcome | Section |
|--------------------------------------|--|----------------|
| The project and project timing | That the investment consists of building a double circuit 400 kV transmission link from Whakamaru to Otahuhu by 2010 | Section 2 |
| Establishing the Need for Investment | That a need exists for investment in the Upper North Island | Section 3 |
| Transmission Options Analysis | That of the options to meet the investment need, a 400 kV HVAC transmission line between Whakamaru and Otahuhu is the best option. | Section 4 |
| Cost-Benefit Analysis | That the net market benefit of 400 kV development is \$133 million better than 220 kV development. | Section 5 |
| Project Cost | That the capital cost of the 400 kV solution is approximately \$460 million | Section 6 |
| Approval Sought | That Transpower seeks approval for all expenditure associated with the project under the transitional provisions in the Rules | Section 7 |

For full information on Transpower's 400 kV North Island 400 kV Grid Upgrade, including a full copy of the Investment Proposal summarised here, visit www.gridupgrade.co.nz.

2 The Project and Project Timing

The proposed investment is the construction of a 400 kV transmission interconnection between the Whakamaru and Otahuhu substations, including:

- A 400 kV, double circuit, steel lattice tower, overhead transmission line of approximately 200 km from Whakamaru substation to a new underground cable transition station near Ormiston Road (south of Otahuhu substation).
- A 400 kV, double circuit, underground cable from the underground cable transition station into Otahuhu substation with a route length of approximately 9 km.
- New 400/220 kV substation (including interconnecting transformers) at Whakamaru substation site.
- New 400/220 kV substation (including interconnecting transformers) at Otahuhu substation site.
- Dismantling the Arapuni to Pakuranga 110 kV transmission line in full and reinforcement of the system where appropriate.

Transpower has concluded that the proposed investment is required to be commissioned by 2010 to ensure Transpower's grid reliability standards can continue to be met in the upper North Island. Therefore all major project milestones are critical to the successful implementation of the proposed investment.

The critical dates required to be met to avoid delays to the commissioning of the proposed investment are:

- registration of interest in transmission line construction: August 2005
- lodgement of the notice of requirement: 13 April 2006
- commencement of compulsory acquisition process for property rights (if required): 14 April 2006
- commencement of tender process for the Engineering, Procurement, Construct contract: 10 April 2006
- Commencement of Design, Procure, Construct Process: 6 November 2006
- Final Commissioning: 27 May 2010

3 Establishing the Need for Investment

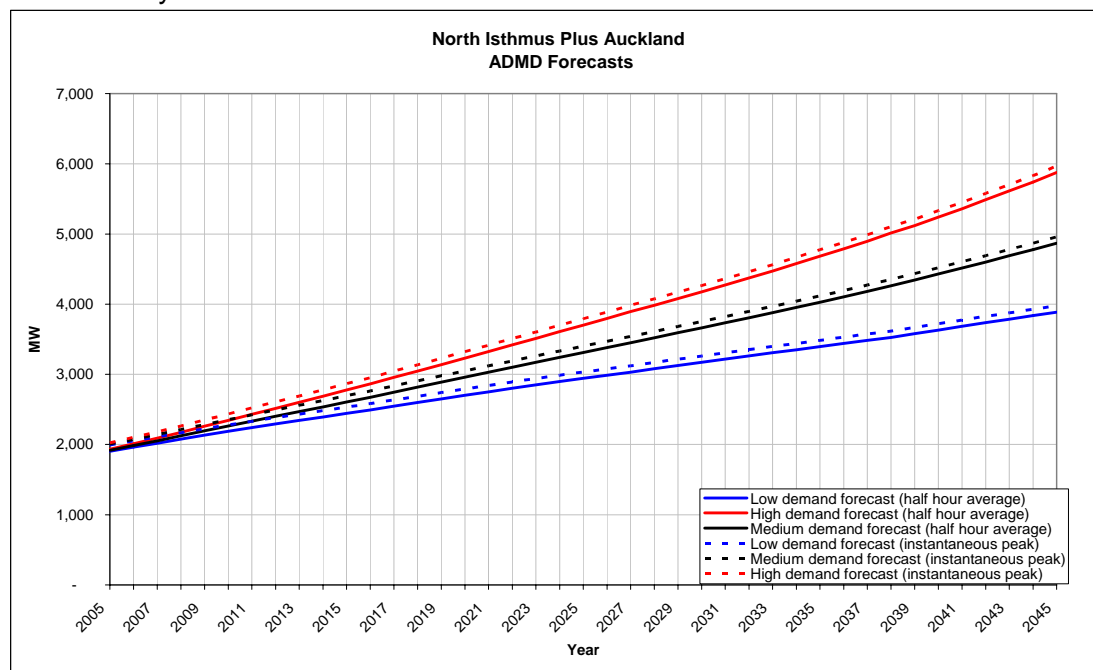
3.1 Overview of Process and Inputs

The need for investment is determined by four inputs - forecast demand, forecast generation, the acceptable level of grid reliability and the capacity of the existing transmission system in the upper North Island. The need and the timing of the investment is determined by an assessment of the future power system capacity required, using these inputs as parameters.

The basis for each of the four inputs is briefly described below:

Forecast Demand

Forecast demand on a regional basis was extrapolated from the 40 year forecast of the Electricity Commission's 2005 national electricity consumption, using regional population figures obtained from Statistics New Zealand. Two other inputs – forecast distributed generation (i.e generation beyond Transpower's connection points), and historical (i.e actual) metered average half hourly peak demand were then used to determine an After Diversity Maximum Demand (ADMD) Forecast for the region for the next 40 years.



Generation Dispatch

The following generation stations were assumed to be dispatched as part of the power systems analysis. It should be noted that this is a critical assumption and the loss of any local generation including that from Huntly will reduce the power transfer limits into Auckland even further. Transpower considers that it is reasonable and prudent to allow for some level of generation unavailability in the region. However the level of generation unavailability that is prudent to assume is highly contentious and there is no clear international standard to apply. As a minimum it is important for all customers and stakeholders to understand the relationship between generation availability and the power system transfer capability so that they can form their own view on the appropriate level of risk to take.

| Generating Station | Installed Capacity MW |
|---------------------------|------------------------------|
| Glenbrook ¹ | 55 |
| Otahuhu CC | 365 |
| Southdown | 122 |
| Huntly ² | 1405 |
| TOTAL | 1947 |

Generation Scenarios

Five different generation scenarios were developed by Transpower to reflect how the uptake of electricity generation resources – gas, coal, renewables might be affected in the future by either scarcity or regulatory mandate. These scenarios are largely consistent with the Electricity Commission five generation scenarios and are only used to assess the economic robustness of the proposal in accordance with the Grid Investment Test.

Grid Reliability Standards

Transpower's grid reliability standards are to plan its network such that the system is in a secure state with all transmission facilities in service and in a satisfactory state following a single contingent event (for example the outage of a generation station or transmission line). This is typically known as a N-1 security standard.

Existing Transmission System

The existing transmission system includes the core transmission lines into Auckland together with tactical upgrades Transpower had earlier identified to make optimal use of existing assets up until a major investment is required. The transmission system also includes 630 MVAR of grid connected capacitors and approximately 240 MVAR of distribution capacitors.

3.2 The System Adequacy Analysis

Using the inputs identified above as parameters, an assessment of the adequacy of the upper North Island transmission system is undertaken. That assessment involved undertaking specific power system studies to determine:

- The thermal limits in the region (i.e. the point at which assets may become overloaded following an outage event on the system)
- The voltage collapse limits in the region (i.e. the point at which the upper North Island regions are at risk of voltage collapse causing possible total or partial loss of supply to the upper North Island regions)
- The transient 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).

¹ For cogeneration plants, the average monthly dispatch is assumed

² Generation from power stations at Huntly is included in the table above because, while it is located in the Waikato region, its proximity to the Auckland region (compared to generation at Whakamaru), means that it does have an effect on supply security.

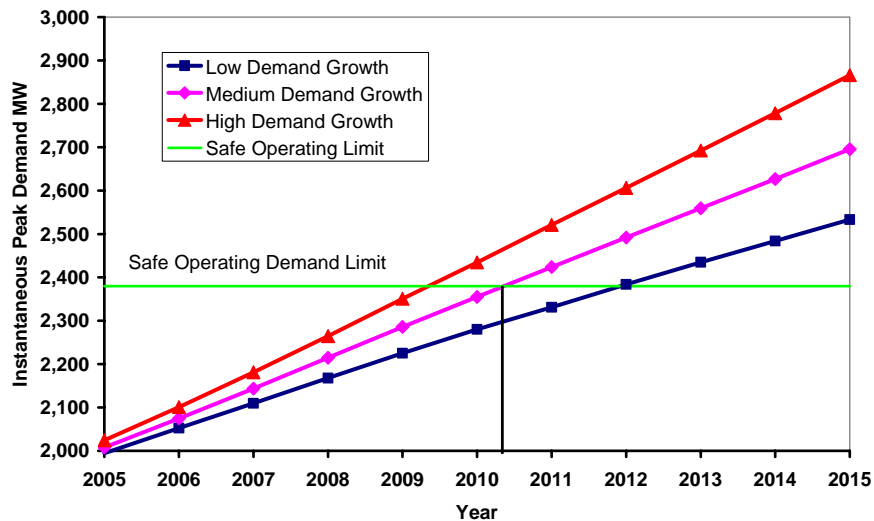
3.3 Conclusion from Power System Assessment Studies

The power system studies confirmed that the safe operating limit for the power system of approximately 2375 MW is exceeded in 2010 under a medium growth forecast, 2009 under a high growth forecast, and 2012 under a low growth forecast:

Voltage collapse was the mode of constraint that is limiting power transfers into the Auckland and upper north island regions.

The N-1 contingent events that limits power transfer under voltage stability criteria are the loss of the Otahuhu B combined cycle power station or the Otahuhu-Whakamaru C line.

System Adequacy Under Low, Medium and High Load Growth Scenarios



4 Transmission Option Analysis

4.1 Process Overview

Transpower investigated a number of transmission options to meet the need identified above. These involved consideration of the following options.

| Option | Transmission Voltage |
|---|----------------------|
| High Voltage Alternating Current (HVAC) | 220 kV |
| | 330 kV |
| | 400 kV |
| | 500 kV |
| Classical High Voltage Direct Current (HVDC) | 350 kV |
| | 500 kV |
| Medium Power High Voltage Direct Current (HVDC Light) | Less than 200 kV |

The option of using the under ground cables for HVAC and HVDC transmission is also considered.

Transpower undertook a high level assessment of these options against technical, economic and environmental criteria.

4.2 Transmission Technology Options

As with most countries, New Zealand's core transmission lines are high voltage alternating current (HVAC). This generally reflects the greater flexibility, reliability and lesser cost compared to HVDC alternatives.

The existing HVDC link in New Zealand (linking the North and South Islands) is predominantly deployed as a means of transferring bulk energy from the large hydro generation stations in the South Island to the larger areas of demand in the North Island.

HVDC Options

For the purposes of the investment in the upper North Island, Transpower examined HVDC transmission options including the possible benefits it might provide through staging the complete project over a number of years, thereby deferring some of the major cost impacts over time.

Following assessment of a number of possible HVDC options Transpower selected three options for final consideration:

- A new HVDC link, of HVDC Classic or HVDC Light technology, between Whakamaru and Otahuhu
- Extension of the existing inter-island HVDC transmission system to Auckland

HVDC link between Whakamaru and Otahuhu

The Classical HVDC 350 kV Bipole link while providing some environmental advantages over HVAC is otherwise a non-preferred solution for the following reasons:

- A HVDC solution is inherently complex, containing a large number of components at which partial or total failure can occur. Furthermore it does not provide the same reliability as a HVAC system.
- A HVDC solution provides less flexibility for future grid expansion and will continue to be associated with higher levels of capital investments compared to the HVAC options. For example, once established, the ability to tap off the system to other points of demand or generation is very limited. HVDC expansion is therefore constrained in its possible development paths and does not cater well for a range of possible generation development futures.
- The cost of a HVDC solution is far higher than a similar HVAC system. Even with staging, the solution is still found to be more expensive compared to the HVAC options.
- The lead time required for HVDC development is in the order of 5-6 years. The 2010 deadline would tend to compress the time available for implementation increasing the technological and commercial risks to the project overall.

Extension of the existing HVDC Link to Auckland

Extension of the existing HVDC link to Auckland was a non-preferred solution for the following reasons:

- It would only provide up to 700 MW of “non-firm” additional transmission capacity into the Auckland area. By comparison, a 400 kV option would provide about 1000 MW of firm capacity (or 2000 MW of non-firm capacity)
- More significantly, extension of the existing link would not provide supply security during dry years in the South Island (such as happened in 2001 and 2003). In these situations there would be little power available to be transferred north. So even if implemented, there would still have to be further HVAC grid augmentation into Auckland to cover for dry year risk.

HVDC Light

“HVDC Light” employs different technology than classical HVDC. This technology, while resulting in smaller converter stations, is constrained by lower operating voltages, the need for underground cables, and higher conversion and transmission losses. Analysis determined that HVDC Light was not appropriate for moving forward for the following reasons:

- The present state of technology allows for undergrounding only, and the maximum operating voltage is below 200 kV. This would mean for the Whakamaru to Otahuhu route, several underground cables would be required using multiple routes.
- Underground land based cables are not as reliable as overhead line options due to the large number of joints in land cables (i.e potential points of failure), and the substantial mean time to repair any failure.
- The cost of HVDC Light transmission is in the order of \$2.1 billion.

4.3 Voltage Options

As well as identifying AC as the preferred technology, the options analysis also looked at the preferred voltage level. Two broad options were identified – continuation of 220 kV development as New Zealand’s core grid voltage, or selection of a new maximum voltage (either 330, 400 or 500 kV) to be introduced as the backbone transmission voltage in the North and South Islands.

220 kV Development

The existing 220 kV system could be developed to meet the forecast demands on the power system. However a 220 kV grid development plan would also require the greatest number of new transmission lines to be built, especially between Auckland and Whakamaru where up to four additional lines might be required by 2040. Transpower considers that the continuation of a 220 kV core grid into Auckland is the least feasible from an environmental and property perspective due to the need for many additional transmission routes traversing what is already a relatively tight geographical corridor.

330 kV Development

This option considers adopting 330 kV as the main core grid voltage for the future long term development of New Zealand's transmission system, augmenting the transmission capacity of the present 220 kV system. A possible perceived advantage of 330 kV compared to any higher voltage was that existing 220 kV transmission lines, might, with modification, be able to operate at 330 kV. However, further analysis confirmed that upgrading the existing lines was not practical for a number of reasons, including:

- The foundations would have to be strengthened or replaced as existing foundations are inadequate for the heavier loading required for 330 kV lines.
- The existing 220 kV towers have insufficient strength to sustain the loads associated with a major upgrade of capacity, while also causing clearance problems if operated at a higher voltage.
- Long continuous line outages would be required during the course of conversion, with the associated risk that electricity supply to customers would be interrupted.
- Any such upgrades would not be able to be achieved under Transpower's "existing use" rights under the Electricity Act 1992. Therefore the option provides no advantage in terms of avoiding the need to acquire property rights and consents under the Resource Management Act 1991.
- There is no cost advantage in upgrading the existing lines to 330 kV than building a new line.

Preliminary analysis has also shown that 330 kV option does not provide any significant economic advantage over the other transmission voltages. As the possibility of upgrading existing lines was a main reason for considering 330 kV, it was considered that 330 kV should not be deliberated on further.

400 kV Development

400 kV provides similar outcomes to 220 kV development in terms of system security and asset availability criteria. The key difference lies in the economic and environmental effects. Specifically, the 400 kV option requires substantially fewer transmission lines, and the higher voltage reduces transmission losses substantially over 220 kV development. The economic benefit of the 400 kV solution over 220 kV development was also found to be significantly higher (described in Section 4). Against the other options considered, 400 kV development means less transmission routes over time compared to 330 kV while providing the right fit for capacity compared to 500 kV.

500 kV Development

This option considered development of 500 kV as the next voltage level for the long term development of the New Zealand Grid. Studies showed that while the 500 kV met capacity requirements from Whakamaru to Auckland, it would tend to provide overly high capacity in the other parts of the core grid. Additionally, the environmental effects would be greater than 400 kV, without any real advantage.

4.4 Undergrounding

Transpower investigated a range of issues associated with partial or complete undergrounding of the proposed 400 kV AC transmission link between Whakamaru and Otahuhu substations.

It was determined that if present grid availability was to be maintained, the failure rates and outage times for 400 kV underground links would have to be equal to or better than those for existing 220 kV lines. This could not be proven by international experience. In particular, repair times for faults on cables, joints and terminations are much longer than for overhead lines and at best would take between 10 and 19 days, under the most optimistic scenario (eg availability of spares, skilled labour etc).

Additionally, the cost of undergrounding would be significantly expensive compared to overhead transmission. The costs would be in the order of a 10:1 ratio. These costs would be further increased by the need to provide intermediate stations at approximately 50 km intervals to provide compensation for charging current. Underground cables require a longer lead time in manufacture and procurement, and together with the requirement for specialised cable deploying equipment, and skilled jointing labour, they make a 2010 commissioning date unrealistic.

Finally, the operational flexibility of cables compared to overhead lines is limited because of the number of issues that need to be addressed and monitored constantly - for example, charging current compensation and harmonic resonance etc.

In conclusion it is considered that underground cables are not a technically fit for purpose solution to meet the need.

5 Net Market Benefit

A cost-benefit analysis was carried out in order to assess the proposed investment against the Electricity Commission's requirements.

The assessment confirmed that a long run development plan for the transmission network at 400 kV is more economic than continuing with incremental augmentation at 220 kV. The expected net market benefit of a 400 kV development plan over a 220 kV development plan is estimated at \$133 million, as the table below attests:

| 400 kV Advantage over Base Case \$million (discounted) | | | | | | |
|---|--------------|--------------|--------------|--------------|--------------|----------------|
| Generation Scenario numbered → | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | Average |
| Line capital costs | 52 | 3 | 120 | 23 | 117 | 63 |
| Substation capital costs | -79 | -66 | -101 | -64 | -88 | -79 |
| Property | 98 | 43 | 132 | 13 | 106 | 78 |
| O&M | -6 | -7 | -8 | -8 | -11 | -8 |
| Dismantling costs | 0 | 0 | -2 | 0 | 0 | 0 |
| Project Management Costs | 12 | 5 | 19 | 5 | 13 | 11 |
| Approval Costs | -6 | -7 | -6 | -7 | -7 | -7 |
| Total Costs | 71 | -29 | 153 | -39 | 130 | 57 |
| Avoidance of unserved energy | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy loss differences | 95 | 75 | 105 | 18 | 85 | 76 |
| Differences in energy costs | 0 | 0 | 0 | 0 | 0 | 0 |
| Differences in carbon costs | 0 | 0 | 0 | 0 | 0 | 0 |
| Differences in ancillary service costs | 0 | 0 | 0 | 0 | 0 | 0 |
| Generation reliability value difference | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Benefits | 95 | 75 | 105 | 18 | 85 | 76 |
| Net Market Benefit 400 kV | 166 | 47 | 258 | -21 | 215 | |
| Expected Net Market Benefit 400 kV | | | | | | 133 |

The proposed investment was also found to have a substantially higher net market benefit than the best case alternative to transmission of a diesel fired peaking plant. The best alternative was found to have an expected net market benefit ranging between \$130 to \$240 million less than the proposed 400 kV transmission investment.

6 Project Capital Cost

The project capital cost was determined to be in the order of \$460 million. However, it was emphasised that this figure is subject to some level of uncertainty, simply because the project is still 5 years from completion. In the Investment Proposal, Transpower identified the magnitude of costs with an expectation that actual costs reasonably incurred in relation to the approved project would be recovered through the transmission pricing methodology.

A breakdown of the estimated magnitude of costs is given below:

| Category | Item | Cost \$m (2005 Real) |
|--------------------|--|-------------------------|
| Investigations | Preliminary engineering, environmental and property work to establish preferred route and lodge NoR. | 20 |
| Property | Acquisition of property rights | 97 |
| Environmental | Acquisition of designations and resource consents | 11 |
| Transmission works | 400 kV line Whakamaru to Otahuhu | 120 |
| | Substations – Otahuhu | 66 |
| | – Whakamaru | 33 |
| | Cable | 84 |
| Dismantling | Arapuni to Pakuranga Line | 4 |
| Project Management | | 25 |
| Total | | 460 |

7 Approval Sought

The proposal set out Transpower's proposed investment comprising a 400 kV high voltage alternating current (HVAC) transmission line between Otahuhu and Whakamaru in the upper North Island, for assessment by the Electricity Commission.

Transpower made the submission under the transitional provisions in the Electricity Governance Regulations 2003 ("EGRs") in view of the tight timeframes involved with the Project in order to (among other things) trigger the Commission's process for consideration of the proposal.

Transpower sought approval from the Electricity Commission under Rule 16 of Section III of Part F for all expenditure on the following:

- Investigation and initial design of the proposed investment;
- Acquisition of property rights for the proposed investment;

- Acquisition of designation and resource consents for the construction of the proposed investment;
- Design, procurement, construction and commissioning of the overhead transmission lines, substations and underground cables forming part of the proposed investment;
- Dismantling of existing transmission lines that are required to be removed as the result of the proposed investment, and consequential system reinforcement.