6 Grid backbone

6.1 Introduction

This chapter describes the adequacy of New Zealand's grid backbone to meet forecast demand and anticipated generation development, approved development plans, and further development options for the next 15 years.

The grid backbone (see Chapter 3 for more information) provides the connection between the regions. The regions are described in Chapters 7 to 19.

Prudent transmission network planning considers a range of generation scenarios to meet the forecast growth in demand (see Chapters 4 and 5 for more information) to determine the development option and timing for grid upgrades.

Transmission needs for the grid backbone are identified after the commissioning of committed projects. The identification of transmission needs is indicative only, based on a limited number of load and generation dispatch scenarios, along with the impact of future new generation scenarios. They indicate the possible need for a fuller investigation within the forecast period, with the timing and scope of the investigation determined by new generation developments and demand growth.

The resolving projects to meet the transmission needs are an indicative list only, being possible solutions that will be subject to the Investment Test. They will be developed through the grid planning process as investments to meet the Grid Reliability Standard and/or to provide net market benefit.

For the North Island, the existing and possible future grid backbones are described in Section 6.3, with issues and possible grid upgrades described in Section 6.4.

For the South Island, the existing and possible future grid backbones are described in Section 6.5, with issues and possible grid upgrades described in Section 6.6.

The HVDC link is described in Sections 6.7 and 6.8. The Annual Planning Report (APR) assumed that the High Voltage Direct Current (HVDC) Pole 1 is replaced by Pole 3 in 2012/13.

6.2 Changes since the 2011 Annual Planning Report

Table 6-1 lists the specific issues and projects that are either new or no longer relevant within the forecast period when compared to last year's report.

Table 6-1: Changes since 2011

Issues/projects	Change
No new issues or projects completed since 2011	No change

6.3 North Island grid backbone overview

6.3.1 Existing North Island transmission configuration

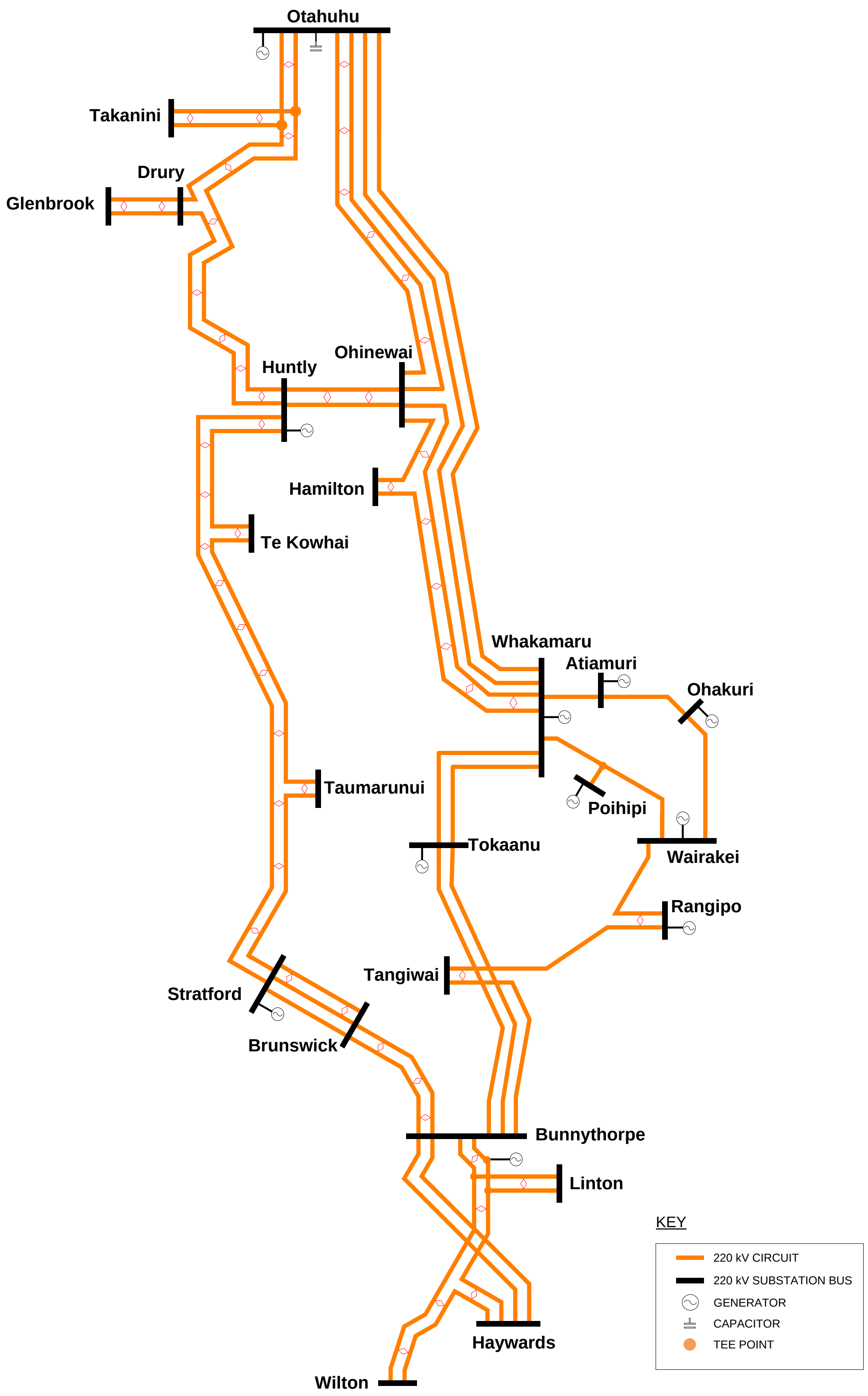
The North Island grid backbone comprises the:

- 220 kV circuits from Wellington to Auckland located along the Central North Island corridor
- 220 kV Wairakei Ring circuits (220 kV circuits between Wairakei and Whakamaru) connecting the major hydro and geothermal generation in the Central North Island to the transmission network, and
- 220 kV circuits from Bunnythorpe to Huntly through Stratford connecting Taranaki generation to the transmission network.

Power flows either north or south on the inter-island HVDC link, depending on the time of day or year. During daylight periods and normal rainfall patterns in the South Island, power tends to flow north. In non-peak periods (late evenings and early mornings) and years of low South Island rainfall, power tends to flow south.

Figure 6-1 shows a simplified schematic of the existing North Island grid backbone.

Figure 6-1: North Island grid backbone schematic



6.3.2 Future North Island grid backbone

Figure 6-2 and Figure 6-3 provide an indication of the North Island transmission backbone development in the medium term (the next 15 years), and longer term (beyond 2027), respectively.

We are building a new double-circuit transmission link from Whakamaru to Auckland, and a new double-circuit transmission line between Wairakei and Whakamaru.

We have submitted an Investment Proposal to the Commerce Commission to replace conductor on the existing 220 kV transmission lines between Bunnythorpe and Haywards. A consequence of the replacement will be to increase capacity on these lines.

We will also investigate an increase in transmission capacity north of Bunnythorpe, either through the Central North Island to Whakamaru, and/or through the Taranaki region and a new line to Whakamaru.

In the longer term, we may increase the transmission capacity through the North Island by increasing the operating voltage on the new overhead transmission line into Auckland to 400 kV. Ultimately we may build a new transmission line connecting Bunnythorpe, Whakamaru, and Auckland, but this is highly dependent on future load and generation growth, and the viability of alternatives.

We will also be looking to provide substation diversity at some critical transmission nodes and strengthen resilience to high impact low probability events.

Voltage stability in the Upper North Island is an ongoing issue. We will continue to study the additional reactive support requirements to maintain Upper North Island voltage stability as regional load continues to grow.

Figure 6-2: Indicative North Island grid backbone schematic to 2027

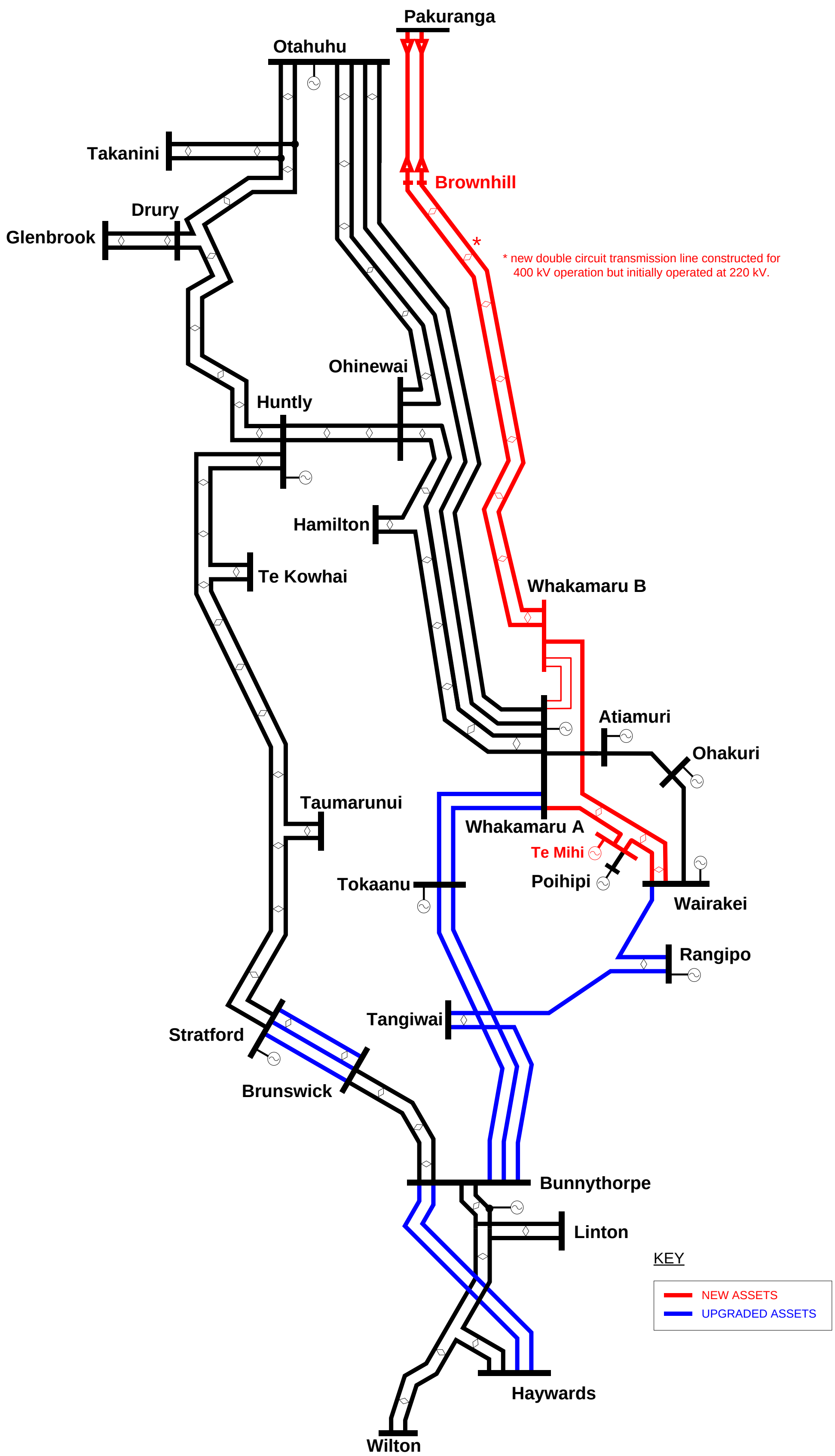
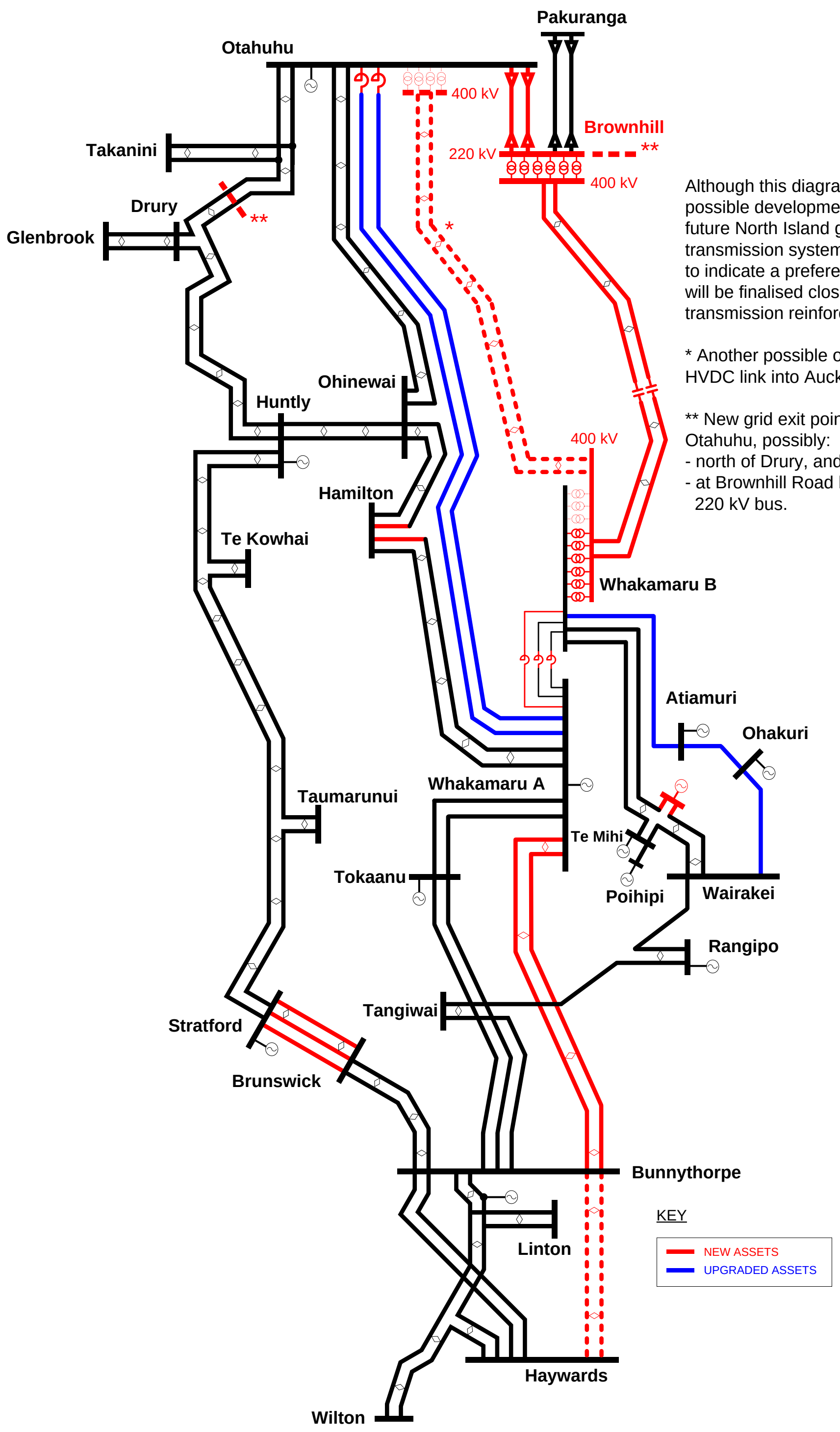


Figure 6-3: Longer term indicative North Island grid backbone schematic



Although this diagram shows a few possible development paths for the future North Island grid backbone transmission system, it is not intended to indicate a preference. Any option will be finalised closer to the date that transmission reinforcement is needed.

* Another possible option is a new HVDC link into Auckland.

** New grid exit point(s) south of Otahuhu, possibly:
- north of Drury, and/or
- at Brownhill Road by extending the 220 kV bus.

6.4 North Island grid backbone issues and project options

The North Island grid backbone comprises five areas indicated in Figure 6-4. Table 6-2 summarises issues involving the grid backbone for the next 15 years. For more information about a particular issue, refer to the listed section number in Table 6-2.

Figure 6-4: North Island grid backbone area

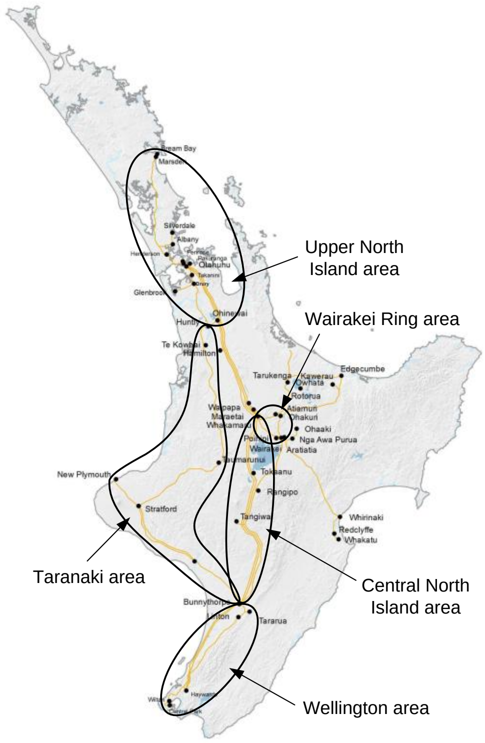


Table 6-2: Grid backbone transmission issues

Section number	Issue
6.4.1	Upper North Island voltage stability
6.4.2	Transmission capacity into Auckland and Northland
6.4.3	Wairakei Ring transmission capacity
6.4.4	Taranaki transmission capacity
6.4.5	Central North Island transmission capacity
6.4.6	Wellington area transmission capacity

6.4.1 Upper North Island voltage stability

Overview

The Upper North Island covers the geographical area north of Huntly, including Glenbrook, Takanini, Auckland, and the North Isthmus.

The transmission capability to supply the Upper North Island load is limited by voltage stability, which in turn is influenced by:

- generation in Auckland and at Huntly
- the reactive power losses due to the transmission system within the Upper North Island
- the reactive power losses due to the transmission system supplying the Upper North Island area, and
- the reactive power demand due to the composition of the load in the area (in particular the proportion and type of motor load).

There are several generator and circuit contingencies that can cause voltage control problems. The worst contingencies include the loss of the:

- Otahuhu combined-cycle gas turbine generator
- Huntly E3P generator (Unit 5)
- 220 kV Huntly–Otahuhu 2 circuit, or
- 220 kV Drury–Huntly 1 circuit.

The Upper North Island load includes a significant proportion of motor load. The behaviour of this load during and following faults influences the regional transmission voltage performance. During a severe fault, motors will decelerate and some can stall. The motors will then draw large currents which in turn delay the voltage recovery after a fault. We have identified that voltage recovery is most at risk in late summer between mid-January and mid-March, when the greatest amount of motor load is connected.

Reactive losses on heavily loaded transmission lines are significant, especially following a circuit tripping when the loading of parallel circuits increases.

The Upper North Island has an enduring need for voltage support because of its reliance on long transmission lines from the south for much of its power. Investment is required every two or three years for voltage support in the Upper North Island. Some component of reactive power support in the Auckland region must be dynamic to avoid the need for shunt capacitor switching after a transmission or generator contingency. The dynamic reactive support may be provided by generators, synchronous condensers, static var compensators (SVCs) or static synchronous compensators (STATCOMs).

Approved projects

Investments in previous years include an SVC at Albany, binary switched capacitors at Kaitaia, ten capacitor banks totalling 600 Mvar at four substations[12], and a short-term contract for reactive support from condensers at Otahuhu[13]. Six capacitors are, or soon will be, decommissioned[14] based on condition assessment.

We have installed power system monitoring equipment to improve our understanding of the Upper North Island power system, specifically load composition and response to transient events.

Projects approved in 2010 by the Electricity Commission under Part F of the Electricity Governance Rules include:

- a STATCOM at Penrose, scheduled for commissioning in 2013
- two STATCOMs at Marsden, scheduled for commissioning in 2014
- a Reactive Power Controller (RPC) to co-ordinate the various dynamic and static devices in the Upper North Island. This work is scheduled to begin in 2012, for commissioning in 2014/2015, and
- demand-side participation.

We issued a Request For Proposals for demand-side participation, but the proposals received were all uneconomic. This was an unexpected result, and the demand-side participation framework is being further developed to unlock its potential (see Section 2.2 for more information).

Other approved projects also have a beneficial effect on voltage stability in the Upper North Island by reducing the reactive power losses in the transmission system.

[12] Capacitors installed in previous years are: Albany 1 x 100 Mvar, Hepburn Road 3 x 50 Mvar, Penrose 4 x 50 Mvar, Otahuhu 2 x 100 Mvar.

[13] The condensers belong to Contact Energy, and were once operated as gas turbine generators, The contract for the condensers expires in 2013 and will not be renewed, as it is more economic to install other reactive support such as STATCOMs.

[14] Capacitors that are, or soon will be, decommissioned are: Albany 2 x 30 Mvar, Henderson 1 x 30 Mvar, and Otahuhu 3 x 30 Mvar.

- The North Auckland and Northland (NAaN) project that increases the transmission capacity in the Auckland and Northland regions (see Chapter 7, Section 7.8.4 for more information).
- The North Island Grid Upgrade (NIGU) project that increases the transmission capacity into the Auckland and Northland regions (see Section 6.4.2 for more information).

Even with these approved projects, voltage stability will be an ongoing issue.

Resolving projects

We have commenced an investigation to determine the amount of additional reactive support required to relieve the Upper North Island voltage stability issue beyond the completion of the NAaN and NIGU projects.

Additional reactive support will be required about every two-three years. This will be a mixture of capacitors and dynamic support such as STATCOMs. The benefits of advancing series compensation on the new transmission link between Whakamaru and Pakuranga will be evaluated also.

The project cost falls within band E. This is a possible investment project to meet the Grid Reliability Standard and we anticipate seeking approval from the Commission in the second half of 2012.

6.4.2 Transmission capacity into Auckland and Northland

Overview

Power transfer to the Upper North Island is dependent on:

- the generation from Huntly, and the transmission capacity between Huntly and Otahuhu, and
- generation from Whakamaru and south of Whakamaru, and the transmission capacity between Whakamaru and Otahuhu.

For the existing system, issues that may arise during periods of high demand and low generation in the Auckland area include:

- an outage of a Huntly–Otahuhu circuit may overload the other Huntly–Otahuhu circuit.
- an outage of a Huntly–Ohinewai circuit may overload the other Huntly–Ohinewai circuit.
- the two 220 kV Otahuhu–Whakamaru circuits may overload during a contingency.
- an outage of the Hamilton–Whakamaru circuit may overload the two 110 kV Arapuni–Hamilton regional circuits.
- an outage of the Hamilton–Ohinewai circuit may cause low voltage at the Hamilton 220 kV bus.

Approved projects

The above issues will be addressed by the North Island Grid Upgrade (NIGU). NIGU includes a number of projects which will:

- increase the power transfer capacity into Auckland
- reduce the loading on the existing 220 kV Otahuhu–Whakamaru and Huntly–Otahuhu circuits, and
- reduce the reactive support needed in the Upper North Island (see Section 6.4.1).

As part of NIGU, we have just completed conversion of the existing 110 kV Pakuranga substation to 220 kV, and the existing Otahuhu–Pakuranga line from 110 kV to 220 kV operation[15].

The remaining NIGU projects include:

- a new substation, Whakamaru B (near the existing Whakamaru substation) and a transition station at Brownhill
- a double-circuit overhead transmission line approximately 190 km from Whakamaru B substation to a transition station at Brownhill, which will:
  - initially operate at 220 kV, and
  - be capable of 400 kV operation in future.
- two 220 kV underground cables from the transition station at Brownhill to Pakuranga substation, rated at 851/890 MVA summer/winter per cable circuit.

After the commissioning of the NIGU projects, eight 220 kV circuits from the south will primarily supply the Upper North Island, with three diverse routes, comprising:

- two circuits from Huntly to Otahuhu (the western path)
- four circuits from Whakamaru to Otahuhu (the central path), and
- two circuits from Whakamaru to Pakuranga (the eastern path).

There are also two circuits between Huntly and Ohinewai connecting the western and central paths.

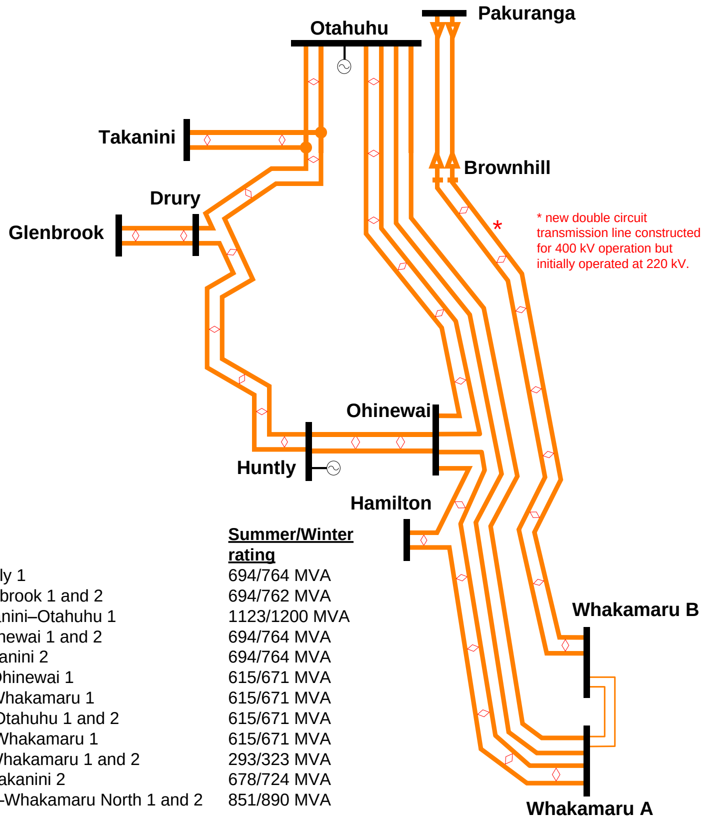
There is a 220 kV connection between Otahuhu and Pakuranga within the Auckland region. The North Auckland and Northland (NAaN) project makes use of the transmission capacity and diversity provided by Pakuranga to increase the capacity and security within the Auckland and Northland regions (see Chapter 7, Section 7.8.4).

The Auckland region is also connected by two smaller 110 kV regional circuits from Arapuni via Hamilton, Bombay, and Wiri to Otahuhu, though their contribution is minor compared to the 220 kV circuits.

Figure 6-5 shows the grid backbone circuits supplying the Upper North Island area.

[15] The Otahuhu–Pakuranga line was constructed at 220 kV, but operated initially at 110 kV.

Figure 6-5: 220 kV Upper North Island grid backbone circuits



Circuit	Summer/Winter rating
Drury–Huntly 1	694/764 MVA
Drury–Glenbrook 1 and 2	694/762 MVA
Drury–Takanini–Otahuhu 1	1123/1200 MVA
Huntly–Ohinewai 1 and 2	694/764 MVA
Huntly–Takanini 2	694/764 MVA
Hamilton–Ohinewai 1	615/671 MVA
Hamilton–Whakamaru 1	615/671 MVA
Ohinewai–Otahuhu 1 and 2	615/671 MVA
Ohinewai–Whakamaru 1	615/671 MVA
Otahuhu–Whakamaru 1 and 2	293/323 MVA
Otahuhu–Takanini 2	678/724 MVA
Pakuranga–Whakamaru North 1 and 2	851/890 MVA

The following sections assess the transmission capability of the circuits into the Auckland and Northland regions following the committed NIGU projects. The assessment is based on representative system conditions, to determine how different generation development scenarios interact with the circuits into Auckland and Northland.

System condition 1 (normal summer's day demand)

This system condition tests a low generation scenario in the Auckland and Northland region during a normal demand period:

- normal summer's day load in the North Island (approximately 85% of summer peak load)
- no thermal generation in Auckland and Northland in service
- low renewable generation in Auckland and Northland, and
- medium to high generation elsewhere.

The circuits into the Auckland and Northland regions have sufficient capacity during a normal demand period and low generation in the Auckland and Northland regions for the duration of the forecast period.

System condition 2 (peak demand)

This system condition tests a high demand period in the Auckland and Northland regions along with the outage of the biggest generator:

- island peak load in the North Island
- high generation in the North Island
- the biggest generator in Auckland is out of service, i.e. Otahuhu C or Huntly E3P, and

- all other thermal generation in Auckland, Northland and Huntly[16] is in service.

Through this it was identified that the Hamilton bus voltage may fall below 0.9 p.u. for the loss of the Hamilton–Ohinewai circuit towards the end of the forecast period.

Impact of generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the circuits into Auckland and Northland.

For system condition 1, all the generation scenarios have minimal impact within the forecast period.

For system condition 2, a low Hamilton bus voltage is seen towards the end of the forecast period in generation scenarios 1 (‘sustainable path’) and 2 (‘South Island wind’). This is because compared to the other generation scenarios, a lower amount of generation is commissioned in the Northland, Auckland and Waikato regions in these scenarios.

Outages

An outage of one of the circuits into Auckland and an outage of the biggest generator in Auckland still maintains n-1 security into Auckland and Northland.

Resolving projects

We will investigate options to resolve the Hamilton bus voltage issue closer to the time it occurs (see Chapter 9, Section 9.9.2 for more information).

Beyond 15 years, the double-circuit line from Whakamaru B to Brownhill will be converted from 220 kV to its construction voltage of 400 kV. This will also require:

- 220/400 kV transformers and associated works at Whakamaru B substation to interconnect with the existing 220 kV system
- a switchyard in the vicinity of the transition station at Brownhill with 220/400 kV transformers and associated works
- 220 kV underground cables to the Otahuhu substation, and
- extensions to the Otahuhu switchyard(s).

6.4.3 Wairakei Ring transmission capacity

Overview

The Wairakei Ring circuits:

- connect the major hydro and geothermal generation stations in the North Island to the grid backbone, and
- supply the Bay of Plenty region from Atiamuri and Ohakuri.

In addition, a new geothermal power station is being built at Te Mihi, and a number of other generation stations which connect directly or indirectly to the Wairakei Ring are in the planning or consent stage.

For the existing system, as this generation develops, an outage of one of the Wairakei Ring circuits may begin to constrain north power flows. Specifically, an outage of the:

- Whakamaru–Poihipi–Wairakei circuit may overload the Wairakei–Ohakuri–Atiamuri circuits

[16] At Huntly, all generator units are in service except E3P is placed out of service for the study. In the 5 generation scenarios, there are new generation connected at Huntly and some units are decommissioned. It ranges from 630 MW to 1,295 MW in 2027 across the 5 generation scenarios.

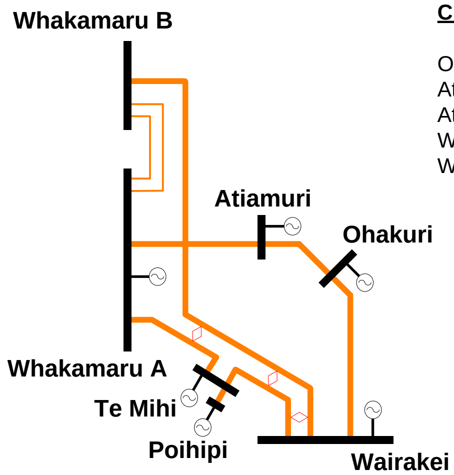
- Wairakei–Ohakuri–Atiamuri circuits may overload the Whakamaru–Poihipi–Wairakei circuit.

Approved projects

To address the above issues, we are building a 220 kV double-circuit line between Wairakei and Whakamaru, to replace the existing single-circuit Wairakei–Whakamaru B line. The line is scheduled for commissioning in 2013, and will increase the power flow capacity through the Wairakei Ring.

Figure 6-6 shows the grid backbone circuits in the Wairakei Ring area after the commissioning of the Wairakei Ring project.

Figure 6-6: 220 kV Wairakei Ring circuits



Circuit	Summer/Winter rating
Ohakuri–Wairakei 1	333/358 MVA
Atiamuri–Ohakuri 1	333/358 MVA
Atiamuri–Whakamaru 1	333/358 MVA
Wairakei–Whakamaru 1	903/994 MVA
Wairakei–Te Mihi–Whakamaru 1	903/994 MVA

The following sections assess the Wairakei Ring transmission capability following the committed Wairakei to Whakamaru Replacement Line Project. The assessment is based on representative system conditions, to determine how different generation development scenarios interact with the Wairakei Ring.

System condition 1 (north flow)

This system condition tests power flowing north through the circuits in the Wairakei Ring towards the Upper North Island:

- island peak load in the North Island
- high geothermal generation in the Wairakei Ring area
- medium to high generation (including peakers) elsewhere to balance generation with demand, and
- HVDC north transfer between 380 MW and, but not exceeding, 1,400 MW.

The following issues were identified:

- The Atiamuri–Ohakuri and Ohakuri–Wairakei circuits may overload for an outage of either the new Te Mihi–Whakamaru or Wairakei–Whakamaru circuits.
- High generation at Kawerau and low demand in the Bay of Plenty may cause higher circuit loading on the Atiamuri–Ohakuri circuit especially during high north flow through the Wairakei Ring circuits. In this scenario, the Atiamuri–Ohakuri circuit may also overload for an outage of the Edgecumbe–Kawerau circuit.

System condition 2 (south flow)

This system condition tests power flowing south through the circuits in the Wairakei Ring towards the Wellington region and the South Island via the HVDC link:

- low North Island load (approximately 45% of peak load)
- high geothermal generation in the Wairakei Ring area
- medium to low generation elsewhere, and
- HVDC south transfer but not exceeding 950 MW.

The Wairakei Ring circuits have sufficient capacity for south power flows for the duration of the forecast period. However, there may be transmission constraints south of the Wairakei Ring (see Section 6.4.5).

System condition 3 (east flow)

This system condition tests the ability of the Wairakei Ring circuits to supply the Bay of Plenty region during high demand and medium generation in that region:

- island peak load in North Island
- high geothermal generation in the Wairakei Ring area
- medium generation in the Bay of Plenty region with the biggest generator in the region out of service (Kawerau geothermal generator is out of service).
- medium to high generation (including peakers) elsewhere to balance generation with demand, and
- HVDC north transfer but not exceeding 1,400 MW.

The following circuits may overload for this system condition.

- The Ohakuri–Wairakei circuit overloads for an outage of the Atiamuri–Whakamaru, Te Mihi–Whakamaru or Wairakei–Whakamaru circuits.
- The Atiamuri–Ohakuri circuit overloads for an outage of the Atiamuri–Whakamaru, Te Mihi–Whakamaru or Wairakei–Whakamaru circuits.
- The Atiamuri–Whakamaru circuit overloads for an outage of the Ohakuri–Wairakei circuit.

Impact of generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the circuits in the Wairakei Ring.

For system condition 1 (north power flow through the Wairakei Ring circuits to supply the Upper North Island), only generation scenarios 1 (‘sustainable path’) and 3 (‘medium renewables’) have a significant impact. These generation scenarios have the lowest net increase in the Upper North Island generation compared to the other generation scenarios. Therefore, there are higher levels of power flow through the Wairakei Ring to supply the Upper North Island load, which may overload the Atiamuri–Ohakuri and Ohakuri–Wairakei circuits.

Generation scenario 1 (‘sustainable path’) has the highest net increase in generation in the Bay of Plenty region compared to the other generation scenarios. High generation and low demand in the Bay of Plenty region may cause the Atiamuri–Ohakuri circuit to overload in a contingent event.

For system condition 2 (south power flow through the Wairakei Ring circuits), all the generation scenarios have minimal impact on the Wairakei Ring circuits within the forecast period.

For system condition 3 (east power flow through the Wairakei Ring), generation scenarios 2 (‘South Island wind’) and 5 (‘high gas discovery’) have the highest impact on circuits supplying the Bay of Plenty region. These generation scenarios have the lowest net increase in generation in the Bay of Plenty region. Therefore, there are higher levels of power flow through the Wairakei Ring to supply the Bay of Plenty, which may overload the Wairakei–Ohakuri–Atiamuri–Whakamaru circuits.

Outages

The main connection to the Bay of Plenty region is through the Wairakei–Ohakuri and Atiamuri–Whakamaru circuits. An outage of either of these circuits puts the whole Bay of Plenty region on n security.

All outages within the Wairakei Ring may also cause generation constraints, which require replacement generation in other areas such as the Auckland region.

Resolving projects

During peak demand periods in the Bay of Plenty region, generation must run in the region to prevent overloading of the Wairakei–Ohakuri–Atiamuri–Whakamaru circuits. Historically, generation in the Bay of Plenty region has been available during peak periods, and we expect this will continue in the short term. However, in the longer term, the region's dependence on local hydro generation may expose it to insufficient transmission capacity within the Wairakei Ring in dry years.

Transmission solutions to prevent overloading of the Wairakei–Ohakuri–Atiamuri–Whakamaru circuits include:

- variable line ratings, which will alleviate some of the overloads in the short term
- reconductoring the Wairakei–Ohakuri–Atiamuri circuits, followed by the Atiamuri–Whakamaru circuit, if required, or
- a new 220 kV Wairakei–Atiamuri circuit (bypassing Ohakuri), followed by a second Atiamuri–Whakamaru circuit, if required.

The Wairakei–Ohakuri–Atiamuri–Whakamaru circuits have already been thermally upgraded, and a further thermal upgrade is not technically feasible. A second Wairakei–Atiamuri circuit is one option which keeps the Bay of Plenty region on n-1 security during outages of the Wairakei–Ohakuri or Atiamuri–Whakamaru circuits. It is unlikely that security to the Bay of Plenty during outages will by itself provide sufficient benefit to justify the second circuit.

We will monitor the generation developments in the Wairakei Ring area and the Bay of Plenty region, to determine if a transmission upgrade investigation is required.

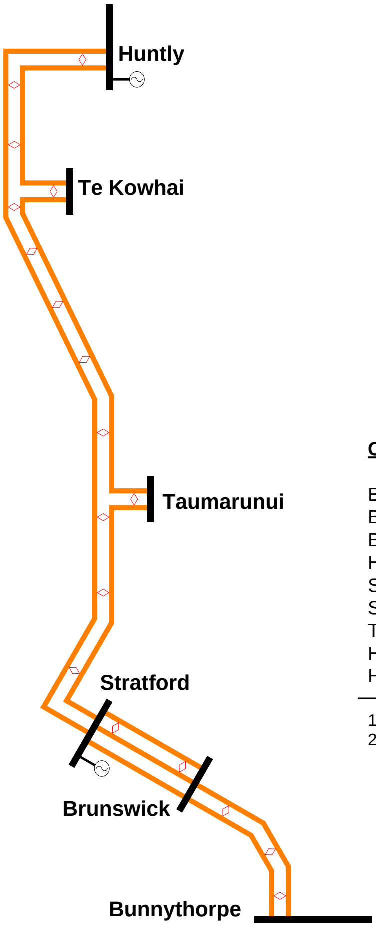
6.4.4 Taranaki transmission capacity

Overview

Taranaki generation is connected to the North Island grid backbone via Stratford with two 220 kV circuits north to Huntly and two circuits south to Bunnythorpe.

Figure 6-7 shows the grid backbone circuits for the Taranaki area between Bunnythorpe and Huntly.

Figure 6-7: 220 kV circuits between Bunnythorpe and Huntly



Circuit	Summer/Winter rating
Bunnythorpe–Brunswick 1 and 2	695/712 MVA[1]
Brunswick–Stratford 1 and 3	239/292 MVA
Brunswick–Stratford 2	232/287 MVA
Huntly–Stratford 1	354/354 MVA[1]
Stratford–Taumarunui 1 (from Stratford)	455/455 MVA[2]
Stratford–Taumarunui 1 (from Taumarunui)	343/343 MVA[2]
Taumarunui–Te Kowhai 1	469/492 MVA
Huntly–Te Kowhai 1 (from Huntly)	301/301 MVA[2]
Huntly–Te Kowhai (from Te Kowhai)	469/492 MVA[2]

1. This rating is due to a component other than the conductor.
2. The circuit rating depends on the direction of power flow. This is due to protection settings.

Approved projects

There are no approved grid backbone projects in the Taranaki area.

The following sections assess the Taranaki transmission capability following the committed upgrades in the North Island. The assessment is based on representative system conditions, to determine how different generation development scenarios interact with the circuits out of Taranaki.

System condition 1 (north flow)

This system condition tests power flowing north through the circuits between Stratford and Huntly to Auckland and Northland:

- island peak load in the North Island
- high generation in Taranaki
- the biggest generator in Auckland is out of service i.e. Otahuhu C
- medium to high generation elsewhere to balance generation with demand, and
- HVDC north transfer varies between 380 MW and 1,400 MW depending on generation and demand in the North Island.

For this system condition, an outage of one of the Huntly–Stratford circuits may cause the other circuit to overload especially during high Taranaki generation and low Auckland generation. Also, an outage of one of the Huntly–Stratford circuits may lead to dynamic and transient instability during high Taranaki generation.

For high levels of generation in the Taranaki area, power also flows to Bunnythorpe before flowing north through the Central North Island grid backbone[17].

System condition 2 (south flow)

This system condition tests power flowing mainly south through the circuits between Stratford and Bunnythorpe to the HVDC link:

- low North Island load (approximately 45% of peak load)
- high generation in Taranaki
- medium to low generation elsewhere to balance generation with demand, and
- HVDC varies between 120 MW north transfer and 950 MW south transfer depending on generation and demand in the North Island.

For this system condition, an outage of one of the Brunswick–Stratford circuits may overload the remaining two Brunswick–Stratford circuits[18] and the parallel 110 kV circuits between Stratford and Bunnythorpe.

The 110 kV circuits that overload are mainly the Hawera–Stratford and Wanganui–Waverly circuits, which have been upgraded to a higher rated conductor but the ratings are still limited by substation equipment.

Impact of generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the circuits out of Taranaki.

For system condition 1 (north power flow from Stratford to Huntly), generation scenario 3 (‘medium renewables’) has the highest impact at the end of the forecast period, as it has the lowest net increase in generation in the Auckland and Northland area compared to the other generation scenarios. The significant overloads on the Huntly–Stratford circuits are dependent on:

- Auckland and Northland load
- Auckland and Northland generation, and
- Taranaki generation.

For system condition 2 (south power flow from Stratford to Bunnythorpe), all the generation scenarios have minimal impact within the forecast period on the Taranaki transmission capacity except for generation scenario 5 (‘high gas discovery’). Generation scenarios 1 to 4 include the decommissioning of the Taranaki combined-cycle gas turbine while generation scenario 5 does not. This scenario has a net increase of up to 460 MW of new gas-fired peakers and combined-cycle gas turbines.

Outages

An outage of any of the circuits out of Taranaki i.e. between Stratford and Huntly or between Stratford and Bunnythorpe, may cause generation constraints, which require replacement generation in other areas.

Resolving projects

To prevent overloads on the circuits out of Taranaki during HVDC north and south flow, the Taranaki generation can be constrained. Alternatively, transmission solutions could include:

17 Central North Island 220 kV circuits such as Tokaanu–Whakamaru may overload during high Taranaki generation and HVDC north flow. See Section 6.4.5 for more information about this issue.

18 Central North Island 220 kV circuits such as Bunnythorpe–Tokaanu and Bunnythorpe–Tangiwai may overload before the Brunswick–Stratford circuits overload for high HVDC south flow. See Section 6.4.5 for more information about this issue.

- thermally upgrade and/or reconductor the Brunswick–Stratford circuits
- reconductor the Huntly–Stratford circuits[19], or
- a new transmission line between Taumarunui and Whakamaru.

To resolve the overloads on the 110 kV circuits, Wanganui and Waverly substation equipment is committed for upgrade to allow a higher rating on the 110 kV Hawera–Stratford and Wanganui–Waverly circuits. Upgrade of the Hawera substation equipment is still being investigated and is part of a separate project.

Also, re-tuning of the generator excitation systems and/or installation of power system stabilisers can enhance transient and dynamic stability to transfer power out of Taranaki between Stratford and Huntly.

6.4.5 Central North Island transmission capacity

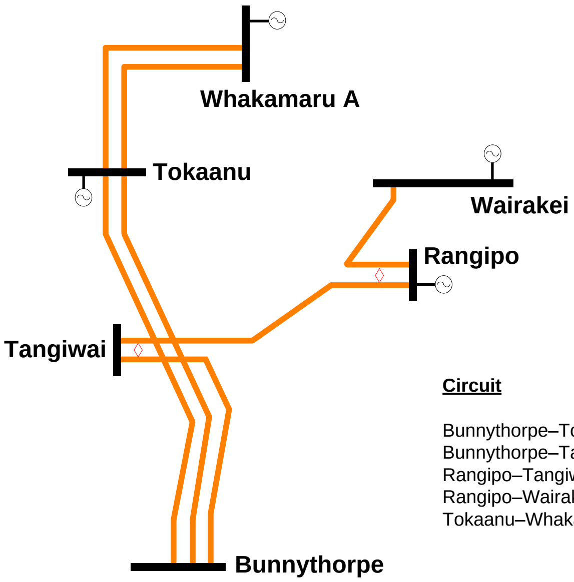
Overview

The circuits between Bunnythorpe and Whakamaru/Wairakei comprise the:

- two Bunnythorpe–Tokaanu–Whakamaru circuits, and
- Bunnythorpe–Tangiwai–Rangipo–Wairakei circuits.

Figure 6-8 shows the grid backbone circuits in the Central North Island area.

Figure 6-8: 220 kV Central North Island circuits



Circuit	Summer/Winter rating
Bunnythorpe–Tokaanu 1 and 2	307/335 MVA
Bunnythorpe–Tangiwai 1	239/291 MVA
Rangipo–Tangiwai 1	239/291 MVA
Rangipo–Wairakei	364/396 MVA
Tokaanu–Whakamaru 1 and 2	307/335 MVA

Approved projects

There are no grid backbone approved projects in the Central North Island area.

The following sections assess the transmission capability of the Central North Island grid backbone following the committed upgrades in the North Island. The assessment is based on representative system conditions, to determine how different generation development scenarios interact with the circuits in the Central North Island.

19 The Huntly–Stratford circuits have a maximum operating temperature of 120°C, which is the maximum practical operating temperature. Therefore, a thermal upgrade is not possible.

System condition 1 (north flow)

This system condition tests power flowing north through the circuits in the Central North Island towards Whakamaru or Wairakei:

- island peak load in the North Island
- high renewable generation including wind, wave, tidal, and solar
- medium to high generation (including peakers) elsewhere to balance generation with demand, and
- HVDC north transfer varies between 50 MW and 1,400 MW depending on North Island generation and demand.

For high generation in the Taranaki area, some of the Taranaki generation flows into Bunnythorpe. This can cause an overload on the Central North Island circuits.

The following circuits may overload for this system condition.

- A Tokaanu–Whakamaru circuit may overload for an outage of the other Tokaanu–Whakamaru circuit, any of the Bunnythorpe–Tangiwai–Rangipo–Wairakei circuits, or one of the circuits between Stratford and Huntly.
- A Bunnythorpe–Tokaanu circuit may overload for an outage of the other Bunnythorpe–Tokaanu circuit, any section of the Bunnythorpe–Tangiwai–Rangipo–Wairakei circuit, or one of the circuits between Stratford and Huntly.
- The Bunnythorpe–Tangiwai–Rangipo–Wairakei circuits may overload for an outage of one of the Bunnythorpe–Tokaanu–Whakamaru circuits or one of the circuits between Stratford and Huntly.

There is a regional 110 kV single circuit between Bunnythorpe and Arapuni (via Mataroa, Ohakune, and Ongarue) which may also overload and constrain north transfer.

System condition 2 (south flow)

This system condition tests power flowing south through the circuits in the Central North Island towards Bunnythorpe:

- low North Island load (approximately 45% of peak load)
- low renewable generation including wind, wave, tidal, and solar
- high geothermal generation in the Wairakei Ring area
- low to medium generation elsewhere to balance generation with demand, and
- HVDC south transfer varies between 580 MW and 950 MW depending on North Island generation and demand.

The following circuits may overload for this system condition.

- A Bunnythorpe–Tokaanu circuit may overload for an outage of the other Bunnythorpe–Tokaanu circuit or any section of the Bunnythorpe–Tangiwai–Rangipo–Wairakei circuit.
- A Tokaanu–Whakamaru circuit may overload for an outage of the other Tokaanu–Whakamaru circuit, any section of the Bunnythorpe–Tangiwai–Rangipo–Wairakei circuits, or one of the circuits between Stratford and Huntly.
- The Bunnythorpe–Tangiwai–Rangipo–Wairakei circuit may overload for outages of a Bunnythorpe–Tokaanu–Whakamaru circuit or one of the circuits between Stratford and Huntly.

There is also low voltage at Bunnythorpe, Tangiwai, and Tokaanu for high HVDC south transfer and low generation in the Lower North Island.

The regional 110 kV circuit between Bunnythorpe and Arapuni (via Mataroa, Ohakune, and Ongarue) may also overload and constrain HVDC south transfer.

Impact of generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the Central North Island circuits.

For system condition 1 (north power flow from Bunnythorpe to Whakamaru/Wairakei), generation scenario 3 ('medium renewables') has the highest impact on the circuits in the Central North Island, as it has the lowest net increase in generation in the Auckland and Northland area compared to the other generation scenarios.

For system condition 2 (south power flow from Whakamaru/Wairakei to Bunnythorpe), generation scenarios 4 ('coal') and 5 ('high gas discovery') have the highest impact on the circuits in the Central North Island, as they have the lowest net increase in generation in the Wellington area. With a lower amount of new generation in the Wellington area, more power is required to flow through the circuits between Whakamaru/Wairakei and Bunnythorpe to supply the demand in the Wellington area and the South Island via the HVDC link. Low voltage at Bunnythorpe, Tangiwai, and Tokaanu only occurs for generation scenario 4, which has the lowest net increase in generation in the Lower North Island.

Outages

An outage of any of the Central North Island circuits may cause generation constraints, which require replacement generation in other areas.

Resolving projects

For the circuits between Whakamaru and Bunnythorpe, the requirement to upgrade is largely dictated by generation development in the area. The upgrade options can be separated into two tranches depending on the amount of new generation.

In tranche 1, the range of options includes:

- limit the power flow on 110 kV regional network between Mataroa and Ohakune through a Special Protection Scheme (SPS), series reactor, phase shifting transformer or a permanent system split (putting four regional grid exit points on n security)
- reconductor the Tokaanu–Whakamaru circuits, and
- thermally upgrade or reconductor the Bunnythorpe–Tangiwai–Rangipo circuit.

Tranche 1 options may enable up to 500 MW of new generation connected at or near to Bunnythorpe. The project cost falls within band F.

In tranche 2, the range of options will enable more generation beyond the options for tranche 1. The range of options includes:

- reconductor the Bunnythorpe–Tokaanu circuits
- provide new transmission capacity between Bunnythorpe and Whakamaru:
  - reuse the existing 220 kV single circuit line route between Bunnythorpe and Wairakei for a replacement double-circuit
  - a new double-circuit 220 kV or 400 kV circuit between Bunnythorpe and Whakamaru, or
  - HVDC light between Bunnythorpe and Whakamaru.
- a new line in the Taranaki area, from Taumarunui to Whakamaru (to divert power flow from the Central North Island grid backbone), and
- Lower North Island-wide System Protection Scheme to enable new generation.

The details and range of options in tranche 2 are still being investigated.

We will monitor generation developments in the Central North Island area, to determine the level of transmission upgrades required including the need for reactive devices to alleviate the low voltage issues.

6.4.6 Wellington area transmission capacity

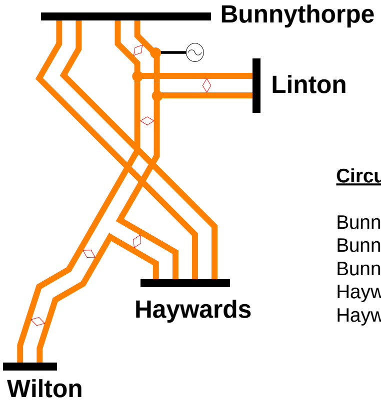
Overview

The 220 kV circuits in the Wellington area between Bunnythorpe and Wellington comprise:

- two circuits connecting directly between Haywards and Bunnythorpe
- one Haywards–Linton–Bunnythorpe circuit, with Tararua Wind Central connected off the Linton–Bunnythorpe section of the circuit, and
- one Wilton–Linton–Bunnythorpe circuit.

Figure 6-9 shows the grid backbone circuits in the Wellington area.

Figure 6-9: 220 kV circuits in the Wellington area



Circuit	Summer/Winter rating
Bunnythorpe–Haywards 1 and 2	307/335 MVA
Bunnythorpe–Linton–Wilton 1	694/764 MVA
Bunnythorpe–Tararua Wind Central–Linton 1	694/764 MVA
Haywards–Linton 1	694/762 MVA
Haywards–Wilton 1	694/739 MVA

Approved projects

There are no approved grid backbone projects for the Wellington area.

We submitted an Investment Proposal to the Commerce Commission in December 2011 to reconductor the two direct Bunnythorpe–Haywards circuits because of condition assessment. The replacement conductor will also provide a small increase in the circuits' rating (from 307/335 MVA to 355/370 MVA). A decision from the Commerce Commission is expected in the second quarter of 2012.

The project cost falls within band F and construction is expected to be completed by the fourth quarter of 2018.

The following sections assess the Wellington area's transmission capability following the committed upgrades in the North Island. The assessment is based on representative system conditions, to determine how different generation development scenarios interact with the circuits in the Wellington area.

System condition 1 (HVDC north flow)

This system condition tests power flowing north through the circuits in the Wellington area towards Bunnythorpe:

- island peak load in the North Island
- high renewable generation including wind, wave, tidal, and solar
- medium to high generation (including peakers) elsewhere to balance generation with demand, and

- HVDC north transfer varies between 50 MW and 1,400 MW depending on North Island generation and demand.

The following circuits may overload for this system condition.

- The two Bunnythorpe–Haywards circuits may overload for outages of the Haywards–Linton–Bunnythorpe circuit (with Tararua Wind Central tee connected) or the Wilton–Linton–Bunnythorpe circuit.
- The Linton–Bunnythorpe circuit (with Tararua Wind Central tee connected) may overload for outages of the Haywards–Wilton circuit or the Wilton–Linton–Bunnythorpe circuit.
- The Haywards–Linton circuit may overload for an outage of the Linton–Bunnythorpe circuit (with Tararua Wind Central tee connected) under certain generation scenarios.
- The Wilton–Linton–Bunnythorpe circuit may overload for an outage of the Haywards–Wilton circuit under certain generation scenarios.

System condition 2 (HVDC south flow)

This system condition tests power flowing south through the circuits in the Wellington area towards Haywards and Wilton:

- low North Island load (approximately 45% of peak load)
- low renewable generation including wind, wave, tidal, and solar
- high geothermal generation in the Wairakei Ring area
- medium to low generation elsewhere, and
- HVDC south varies between 580 MW and 950 MW depending on North Island generation and demand.

For this system condition, the two Bunnythorpe–Haywards circuits may overload for outages of the Haywards–Linton–Bunnythorpe circuit (with Tararua Wind Central tee connected) or the Wilton–Linton–Bunnythorpe circuit.

Some regional 110 kV circuits may also overload and constrain HVDC south transfer. These are the circuit between Bunnythorpe and Arapuni (via Mataroa, Ohakune, and Ongarue) and the two Bunnythorpe–Woodville circuits.

There are also voltage issues for the loss of a 220 kV circuit between Bunnythorpe and Wellington during high HVDC south transfer and low generation in the Wellington area.

Impact of generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the circuits in the Wellington area.

For system condition 1 (north power flow from Wellington to Bunnythorpe), generation scenario 3 (‘medium renewables’) has the highest impact on the circuits in the Wellington area, as it has the lowest net increase in generation in the Auckland and Northland area compared to the other generation scenarios. Generation scenarios 1 (‘sustainable path’) and 2 (‘South Island wind’) have high wind generation at the Linton bus and may cause the Haywards–Linton circuit to overload for outages of the Linton–Bunnythorpe circuit, Haywards–Wilton circuit or the Wilton–Linton–Bunnythorpe circuit. The Wilton–Linton–Bunnythorpe circuits may also overload due to high generation at the Linton bus for an outage of the Haywards–Wilton circuit.

For system condition 2 (south power flow from Bunnythorpe to Wellington), generation scenarios 4 (‘coal’) and 5 (‘high gas discovery’) have the highest impact on the circuits in the Wellington area, as they have the lowest net increase in generation in the Wellington area. With a lower amount of new generation in Wellington, more power is required to flow through the circuits between Bunnythorpe and Wellington to supply Wellington area demand and the South Island via the HVDC link. Low voltages at Bunnythorpe and Linton occur only in generation scenario 4, which has the lowest net increase in generation in the Wellington area.

Outages

An outage of any of the 220 kV circuits in the Wellington area during HVDC north or south flow may cause generation constraints, which require replacement generation in other areas.

Resolving projects

For the two direct circuits between Bunnythorpe and Haywards, we believe that it is uneconomic to increase their rating to increase the transmission capacity (other than the small increase in rating following reconductoring – refer to Approved projects above). However, a higher amount of power transfer between Bunnythorpe and Haywards is possible with a Special Protection Scheme (SPS). The SPS will automatically reduce the power flowing on the HVDC link (after Pole 3 is commissioned) if the two direct Bunnythorpe–Haywards circuits overload, subject to other constraints within the power system. We will monitor the level of constraint caused by these circuits to determine when an investigation to implement an SPS is required.

The overloads on the two circuits between Bunnythorpe and Linton are driven by the amount of generation connected at Linton. We will monitor the amount of generation being connected at Linton to determine if a transmission upgrade investigation is required.

For the two regional 110 kV Bunnythorpe–Woodville circuits, we have a committed project to install an SPS to increase south flow transmission capacity. We will monitor new generation connections to determine if an investigation to re-conductor the circuits to a higher rating is required.

There is significant potential wind generation in the Wairarapa. One option to connect this generation is to build a new 220 kV transmission line from the Wairarapa to Bunnythorpe or Linton.

6.5 South Island grid backbone overview

6.5.1 Existing South Island transmission configuration

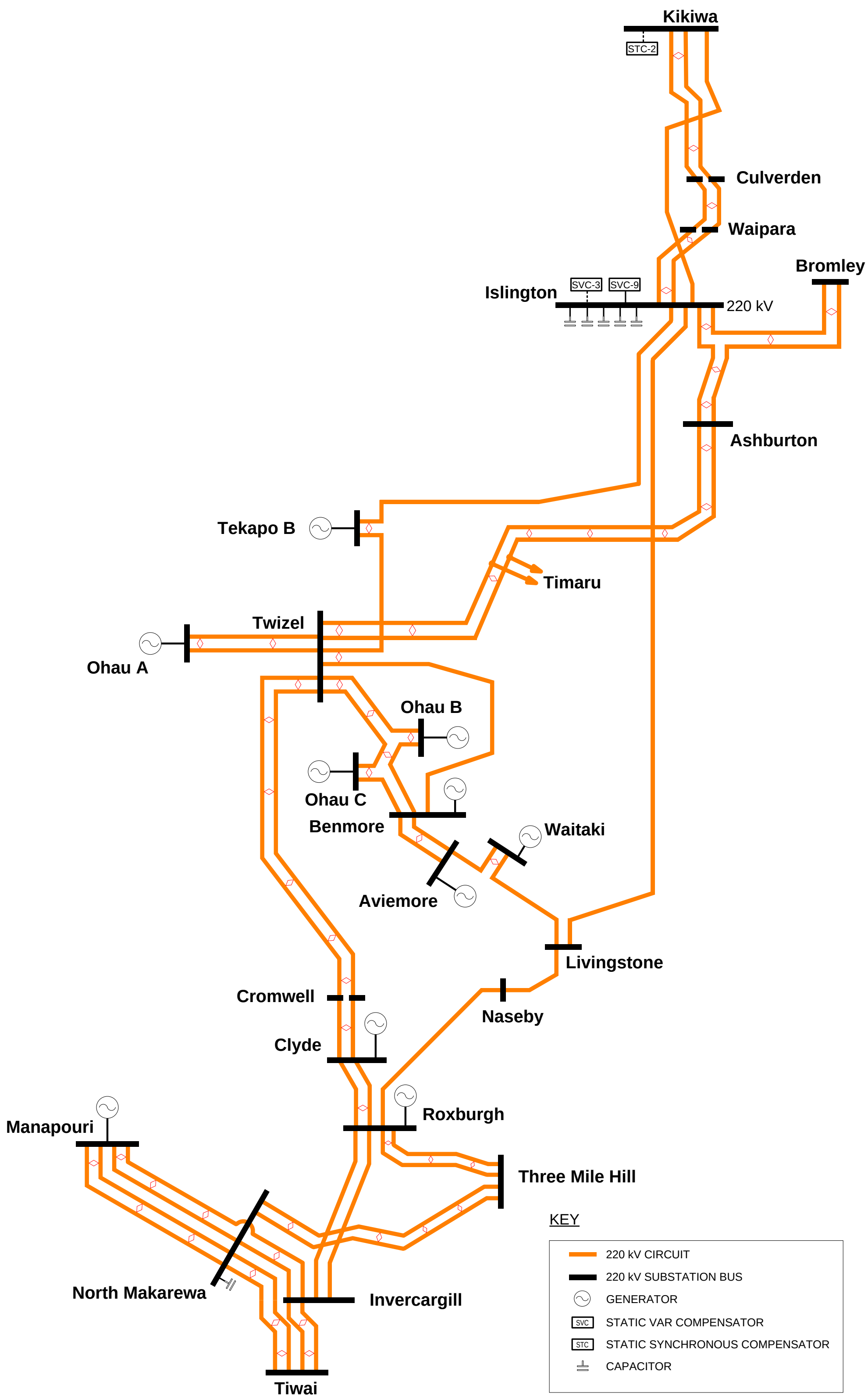
The South Island grid backbone comprises 220 kV circuits with:

- three circuits from Islington to Kikiwa
- four circuits from Twizel and Livingstone in the Waitaki Valley area to Islington
- circuits within the Waitaki Valley, between Twizel and Livingstone, which connect six large hydro power stations and the HVDC link
- three circuits from Roxburgh to Twizel and Livingstone in the Waitaki Valley area, and
- four circuits from Roxburgh to Invercargill/North Makarewa (two via Three Mile Hill) and nine circuits within the Southland area.

Power flows either north or south on the inter-island HVDC link, depending on the time of day or year. During daylight periods, power tends to flow north to meet peak demand. However, during light load periods, power can flow south to conserve the level of South Island hydro storage, especially during periods of low hydro inflow.

Figure 6-10 shows a simplified schematic of the existing South Island grid backbone.

Figure 6-10: South Island grid backbone schematic



6.5.2 Future South Island grid backbone

Figure 6-10 and Figure 6-11 provide an indication of the South Island transmission backbone development in the medium term (the next 15 years), and longer term (beyond 2027), respectively.

We will install an additional bus coupler circuit breaker at Islington, to improve voltage stability for the Upper South Island following a bus fault and to increase security.

Further investments in the Upper South Island to maintain voltage stability to meet load growth will also be required. Presently we are consulting on two options:

- increasing the dynamic reactive support at and around the Islington 220 kV bus, and
- bussing all four 220 kV circuits into the Upper South Island at Geraldine.

In the longer term, further upgrades for the Upper South Island may be required for voltage stability or thermal capacity reasons. Options include:

- extending the 220 kV grid from Kikiwa to Inangahua in the West Coast region[20], to improve voltage stability
- bussing all three circuits north of Islington with an HVDC tap-off near Waipara, and
- a second Islington–Twizel circuit providing a fifth circuit into the Upper South Island.

The Upper South Island voltage stability is an ongoing issue. We will continue to study the additional reactive support requirements to maintain Upper South Island voltage stability as regional load continues to grow.

Within the Waitaki Valley area, there is an approved project to increase the transmission capacity of the Aviemore–Waitaki–Livingstone circuits. There is also an approved project to increase the capacity of the Aviemore–Benmore circuits, which will be reviewed in 2013 to optimise its implementation date.

Between Roxburgh and the Waitaki Valley, there is an approved project to increase the transmission capacity of the Roxburgh–Clyde circuits. There is also an approved project to increase the capacity of the other circuits, which will be reviewed in 2013 to optimise an implementation date.

For the area below Roxburgh, the 110 kV regional network limits the capacity of the 220 kV grid backbone. There is an approved project to remove this regional grid constraint. There is also an approved project to further increase the grid backbone capacity by installing a series capacitor on the North Makarewa–Three Mile Hill circuit, which will be reviewed in 2013 to optimise an implementation date.

We will also look to provide substation diversity at critical transmission nodes to strengthen resilience for high impact low probability events.

[20] There is a 220 kV double-circuit transmission line between Inangahua and Kikiwa, which at present has a circuit on one side only and is operated at 110 kV.

Figure 6-11: Indicative South Island grid backbone schematic to 2027

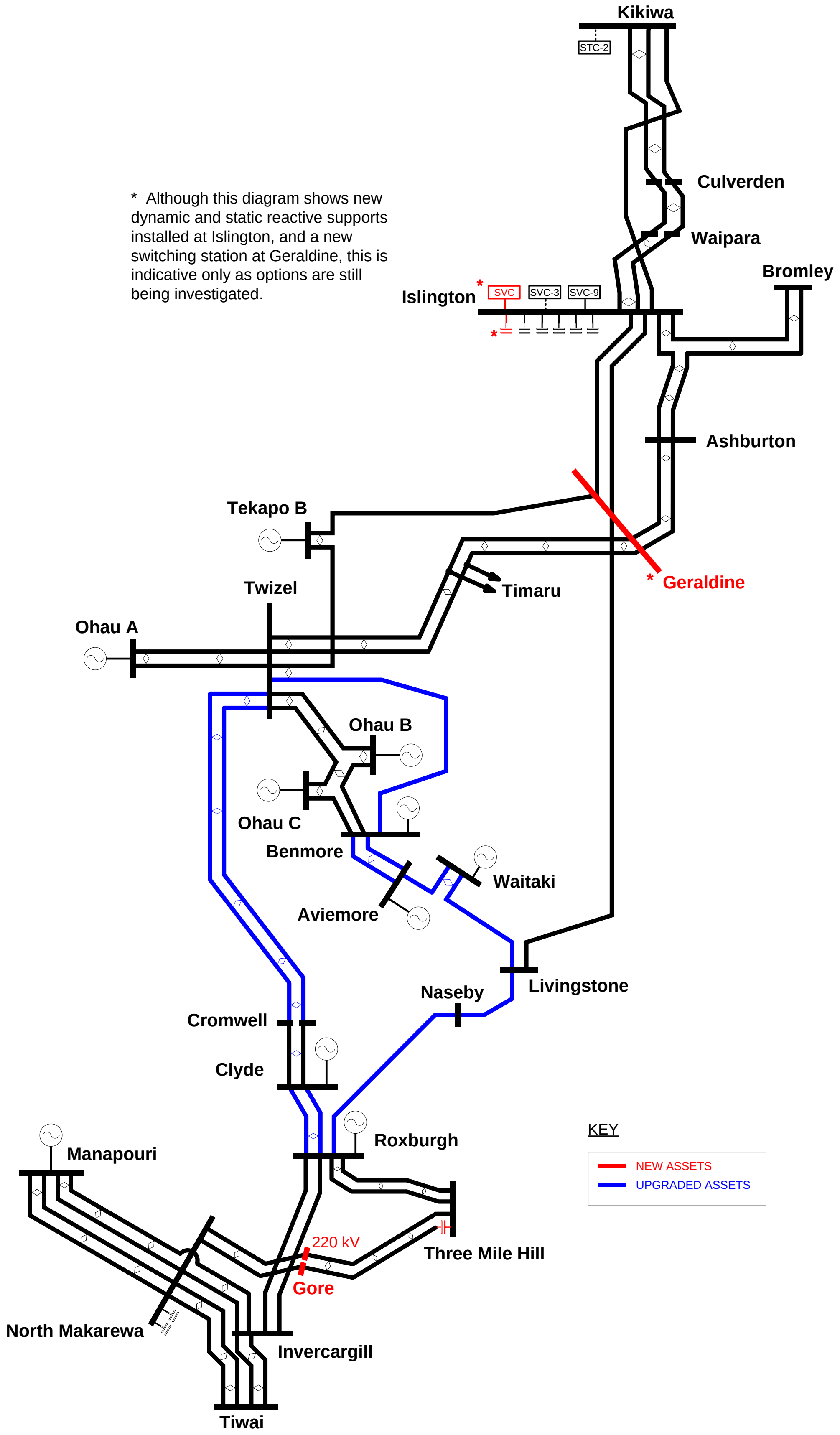
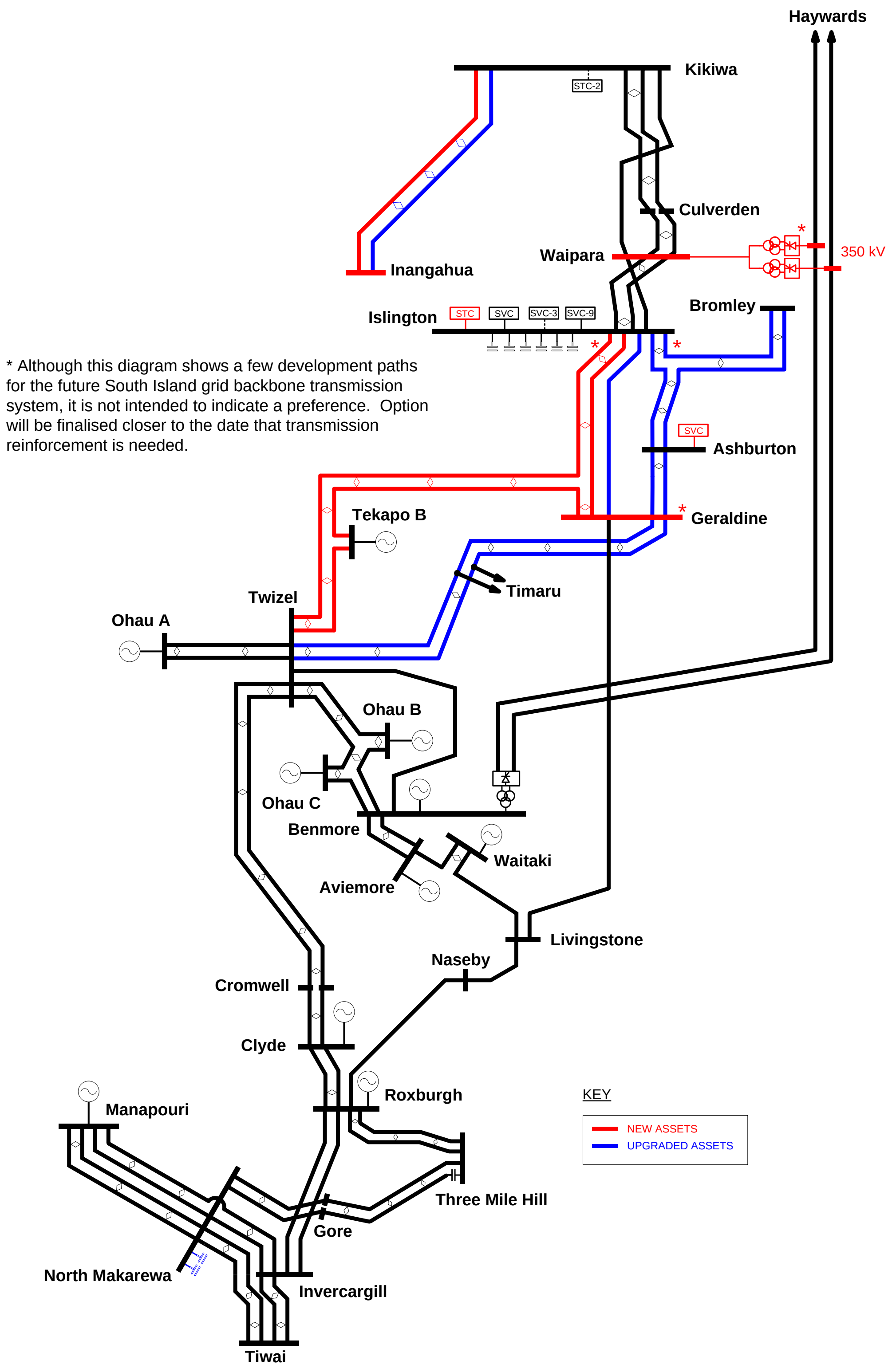


Figure 6-12: Longer term indicative South Island grid backbone schematic



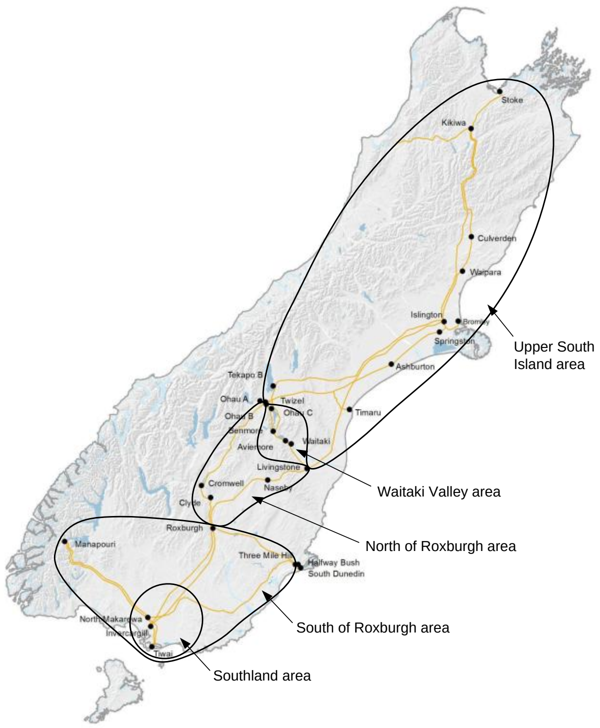
6.6 South Island grid backbone issues and project options

The South Island grid backbone comprises four areas indicated in Figure 6-13. Table 6-3 summarises issues involving the South Island grid backbone for the next 15 years. For more information about a particular issue, refer to the listed section number.

Table 6-3: South Island grid backbone transmission issues

Section number	Issue
6.6.1	Upper South Island voltage stability
6.6.2	Upper South Island transmission capacity
6.6.3	Transmission capacity north of Roxburgh and within the Waitaki Valley
6.6.4	Transmission capacity south of Roxburgh

Figure 6-13: South Island grid backbone area



6.6.1 Upper South Island voltage stability

Overview

Most of the Upper South Island load is supplied through four 220 kV circuits from the Waitaki Valley. The Upper South Island area has relatively little generation compared with load. The generation is connected to the regional grid or embedded within the distribution networks.

The transmission capacity to supply the Upper South Island is limited by voltage stability. Voltage stability within this area is influenced by:

- the reactive power losses due to the transmission system within the area
- the reactive power demand due to load composition in the area (in particular the proportion and type of motor load), and
- generation in the area

Reactive support for the Upper South Island is provided by:

- synchronous condensers and SVCs at Islington
- a STATCOM at Kikiwa, and
- capacitor banks at Islington on the grid backbone and, within the regional grids capacitor banks at Islington, Bromley, Southbrook, Blenheim, Stoke, Greymouth, and Hokitika.

The contingencies which may cause a voltage stability issue are:

- from winter 2016, an outage of an Islington bus section which disconnects a number of transmission elements[21], increasing the reactive power that will be absorbed by the remaining in-service circuits and transformers
- from winter 2017, an outage of the Islington–Tekapo B circuit, and
- from 2017, an outage of an Ashburton bus section.

Approved projects

We regularly invest in grid upgrades to raise the voltage stability limit, to match load growth. Recent investments include a second SVC at Islington and a STATCOM at Kikiwa. Most recently, we installed a Reactive Power Controller (RPC) at Islington to co-ordinate various dynamic and static devices in the Upper South Island.

We intend to install an additional bus coupler circuit breaker at Islington to address Upper South Island voltage stability up to 2017.

Voltage stability will be an ongoing issue which will require regular investments to match load growth.

Impact of generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the Upper South Island backbone grid.

All generation scenarios have new generation or demand side reduction within the Upper South Island. This will improve voltage stability, which may defer or replace the need for transmission investment. Generation scenarios 1 (‘sustainable path’), 2 (‘South Island wind’) and 3 (‘medium renewables’) have the highest amount of new generation. Generation scenarios 4 (‘coal’) and 5 (‘high gas discovery’) have the least new generation over the next five years, and would be insufficient to defer transmission investment.

Outages

An outage of a circuit or other transmission element for maintenance will increase the reactive power losses of the transmission system. This requires maintenance to be scheduled for a low load period, load reduction, generation to be constrained on, and/or additional investment in reactive support.

Resolving projects

We will install a sixth bus coupler at Islington to create an additional bus zone to minimise the equipment tripping following a bus fault, and so improve voltage stability.

We have also commenced an investigation to determine the amount of additional reactive support required in the next tranche of investments to relieve the Upper South Island voltage stability issue. Transmission options include:

- a combination of static and dynamic reactive support around Islington and Bromley, and/or
- sectionalising the 220 kV circuits from the Waitaki Valley to Islington by bussing them at a new switching station near Geraldine; this also requires a short section of new transmission line to bring all circuits to Geraldine.

In the longer-term, transmission options include:

- about 350 Mvar of additional reactive support may be required by 2027, and

[21] The critical Islington bus section outage disconnects: Islington–Tekapo B, Islington–Waipara–Culverden–Kikiwa 2, a capacitor bank, and T7 (220/66 kV transformer).

- reinforcing the Upper South Island transmission capacity (see Section 6.6.2), which also addresses the voltage stability issue.

6.6.2 Upper South Island transmission capacity

Overview

Power transfer to the Upper South Island is through four 220 kV circuits from the Waitaki Valley.

The Islington 220 kV bus is a single major node, supplying a large proportion of the load in Christchurch (along with Bromley), Nelson-Marlborough and the West Coast. There is a risk that high impact low probability single events at Islington can cause a significant or total loss of supply, either with all equipment in service or during maintenance outages.

Approved projects

There are no approved grid backbone projects in the Upper South Island area for transmission capacity.

System condition (north flow)

The Upper South Island has relatively little generation compared with the load, even at minimum load. Therefore, power always flows from the Waitaki Valley northwards.

The n-1 transmission (thermal) limit for the Upper South Island area is forecast to bind towards the end or just beyond the forecast period (2027).

Impact of generation scenarios

The five generation scenarios described in chapter 5 all have new generation north of Islington, or demand response to reduce peak demand. More generation or demand response defers the onset of the n-1 transmission limit.

Outages

"Outage windows" are required so a circuit can be taken out of service for maintenance while managing the grid to provide n-1 security. The number and duration of outage windows available for maintenance depends on the load, load management, and generation within the area. It is possible that insufficient outage windows will be available within the forecast period to enable the required maintenance, or for upgrading circuits.

Resolving projects

Options to address the n-1 transmission capacity towards the end of the forecast period include:

- an HVDC tap-off from the existing HVDC line north of Christchurch
- a new transmission line to Ashburton or Islington.

These resolving projects may need to be brought forward a few years to ensure there are enough opportunities to take equipment out of service for maintenance.

We will monitor the loading on the Upper South Island circuits to determine when a transmission upgrade investigation is required.

6.6.3 Transmission capacity north of Roxburgh and within the Waitaki Valley

Overview

Two sub-areas make up the grid backbone in the area: within the Waitaki Valley, and from Roxburgh to the Waitaki Valley.

The grid backbone within the Waitaki Valley connects:

- the Upper South Island area, at Twizel and Livingstone
- the Waitaki Valley hydro generators[22] at six substations
- the inter-island HVDC link at Benmore, and
- the transmission system to Roxburgh, from Twizel and Livingstone.

The direction and amount of power flowing through the circuits within the Waitaki Valley depends on the load in the Upper South Island, the generation in the area, the amount and direction of HVDC transfer, and the net Otago-Southland load.

The grid backbone from Roxburgh to the Waitaki Valley provides through-transmission to the Otago/Southland area. The direction of the power flow may be north or south, depending on the generation and load in the Otago-Southland area. The power flow within the sub-area is also significantly influenced by the generation at Clyde and, to a lesser extent, by the load off-take at Cromwell and Naseby.

Approved projects

The Clutha–Upper Waitaki Lines Project (CUWLP) is an approved suite of projects[23] to increase transmission capacity for:

- low generation in the Otago-Southland area, which causes high ‘south’ power flows from within the Waitaki Valley to Roxburgh, and
- high generation in the Otago-Southland area, which causes high ‘north’ power flows from Roxburgh to the Waitaki Valley.

The first tranche of projects is to increase the transmission capacity to address high south power flows. We will:

- duplex the Clyde–Roxburgh 1 and 2 circuits in 2013, and
- duplex the Aviemore–Waitaki–Livingstone circuits in 2014.

Duplexing these circuits approximately doubles the south transmission thermal capacity[24] to export power from the Waitaki Valley to Roxburgh, (from 250-280 MW to 560-590 MW)[25]. There is no significant change in the north transmission thermal capacity.

The second tranche of projects is to:

- duplex the Roxburgh–Naseby–Livingstone circuits
- duplex the Aviemore–Benmore 1 and 2 circuits, and
- thermally upgrade Cromwell–Twizel 1 and 2 circuits.

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22 The six hydro power stations that connect to the grid backbone in the Waitaki Valley are: Ohau A, Ohau B, Ohau C, Benmore, Aviemore, Waitaki.

23 The Clutha–Upper Waitaki Lines Project (CUWLP) was previously referred to as the Lower South Island Renewables Grid Upgrade Project, approved by the Electricity Commission in August 2010.

24 The increase in south transmission capacity occurs only after all the referenced circuits are duplexed; there is no significant increase in south transmission capacity with only some of the circuits duplexed.

25 The amount of power that can be exported from the Waitaki Valley to Roxburgh varies with generation, particularly generation at Clyde power station, and varies to a lesser extent with load. The limits are measured across the Livingstone–Naseby and Cromwell–Twizel 1 and 2 circuits in the Roxburgh–Waitaki Valley area.

The primary benefit of the second tranche of projects is to increase the north transmission thermal capacity. When there is high generation in the Otago-Southland area, and at Roxburgh and Clyde, power is exported to the Upper South Island area and/or the HVDC link at Benmore. The increase in transmission thermal capacity is progressive, with increased transmission capacity available at the completion of each upgrade. The north transmission thermal capacity increases from its existing level of 200-590 MW to 790-1,260 MW[26] once all the upgrades are completed.

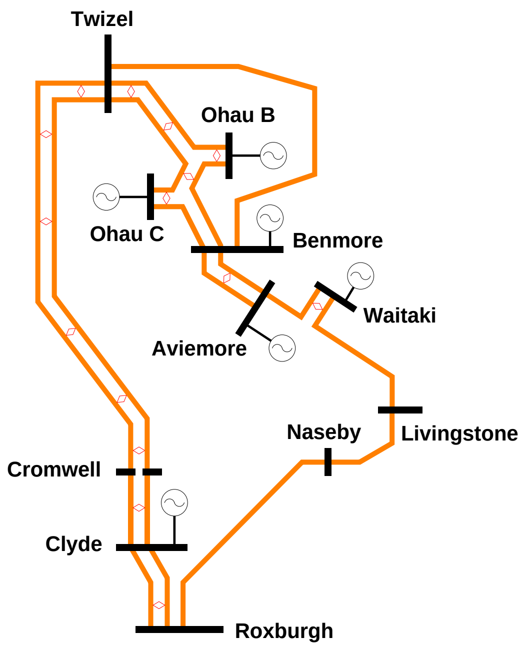
The justification for increasing the north transmission thermal capacity is twofold, to:

- enable full output from existing generators at Clyde, Roxburgh and the Otago/Southland area, and
- enable new generation projects in the Otago/Southland area. We will review the second tranche of projects in 2013, to optimise the timing of the upgrades.

The second tranche also significantly increases the south transmission thermal capacity, to 560–590 MW. However, it is expected that most of this south transmission capacity will not be required.

Figure 6-14 shows the circuits in the Waitaki Valley after the upgrades.

Figure 6-14: 220 kV circuits between Roxburgh and Twizel after CUWLP upgrade



Circuit	Summer/Winter rating
Aviemore–Benmore 1 and 2	609/671 MVA[1]
Aviemore–Waitaki 1	609/671 MVA
Livingstone–Waitaki 1	609/671 MVA
Livingstone–Naseby 1	609/671 MVA[1]
Naseby–Roxburgh 1	609/671 MVA[1]
Clyde–Cromwell–Twizel 1 and 2	561/617 MVA[1]
Clyde–Roxburgh 1 and 2	347/382 MVA
Benmore–Twizel 1	404/493 MVA
Benmore–Ohau B 1	561/617 MVA
Ohau B–Twizel 3	694/760 MVA
Benmore–Ohau C 2	561/617 MVA
Ohau C–Twizel 4	694/764 MVA

[1] The timing to upgrade these circuits will be reviewed in 2013. The summer/winter rating for these circuits prior to upgrade is:
- 202/246 MVA for Aviemore–Benmore 1 and 2, Roxburgh–Naseby–Livingstone 1, and
- 385/470 MVA for Cromwell–Twizel 1 and 2.

The following sections assess the transmission capability following the CUWLP upgrade. The assessment is based on representative system conditions, to determine how different generation development scenarios interact with the Waitaki Valley area.

System condition 1 (north flow)

This system condition tests power flowing from the Lower South Island to the upgraded HVDC link:

- maximum South Island generation

[26] The amount of power that can be sent from Roxburgh to the Waitaki Valley varies with generation and load. The large range for north transmission capacity is mainly due to the effect of generation at Clyde, ranging from full output of 432 MW to 0 MW. The limits are measured across the Naseby–Roxburgh and Clyde–Roxburgh 1 and 2 circuits.

- off peak South Island load (approximately 62% of island peak)
- maximum HVDC north transfer of 1,400 MW

There were no issues with transmission capacity for north flow for the forecast period.

System condition 2 (south flow)

This system condition tests power flowing south of Roxburgh/Clyde during a period of extremely low southern generation fully utilising the upgraded HVDC links south flow capacity. To avoid overloading the grid backbone (after the CUWLP projects are completed):

- in 2018, a minimum total of about 362 MW of generation is required at Manapouri, Roxburgh and Clyde power stations
- in 2027, a minimum total of about 670 MW is required at Manapouri, Roxburgh and Clyde power stations.

Impact of generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the circuits within the Waitaki Valley area.

There were no issues with transmission capacity for north flow for all generation scenarios.

High levels of power flow south towards Roxburgh, with high levels of HVDC south flow, overloaded the Benmore–Twizel circuit.

As noted in the previous section for system condition 2 (south flow), minimum levels of generation are required south of Roxburgh/Clyde. Any new generation south of Roxburgh increases the options for providing the minimum generation requirements, assisting in the management of the power system.

Outages

The transmission capacity is reduced during outages, which may require generation in the Waitaki Valley or Lower South Island area to be constrained.

Resolving projects

For very high power flows from the Waitaki Valley to the Lower South Island, the Benmore–Twizel circuit capacity will need to be increased. Transmission solutions to prevent overloading of the Benmore–Twizel circuit include[27]:

- variable line ratings to alleviate some overloads in the short term, and
- thermally upgrading and/or reconductoring the Benmore–Twizel circuit.

We will monitor the loading of the Benmore–Twizel circuit to determine if a transmission upgrade investigation is required.

Any further increase in south transmission capacity beyond that provided by the suite of projects provided by CUWLP will require a new transmission line. We will monitor the load and minimum generation levels required to determine if a new line investigation is required. The present load forecasts do not indicate the need for a new transmission line.

[27] We believe that only a relatively small increase in the rating of the Benmore–Twizel circuit is required (about 20%), and that reconductoring the circuit is not required.

6.6.4 Transmission capacity south of Roxburgh

Overview

The grid backbone south of Roxburgh is primarily a six circuit “triangle” between Roxburgh, Three Mile Hill and Invercargill/North Makarewa. There are also nine circuits connecting Invercargill, North Makarewa, Manapouri and Tiwai.

There is a low capacity 110 kV regional network which operates in parallel with the grid backbone between Roxburgh, Halfway Bush and Invercargill (see Chapter 19). The capacity of this regional network limits the capacity of the grid backbone.

The magnitude and direction of power flows on the grid backbone are dominated by the large hydro generator at Manapouri and the large load at Tiwai.

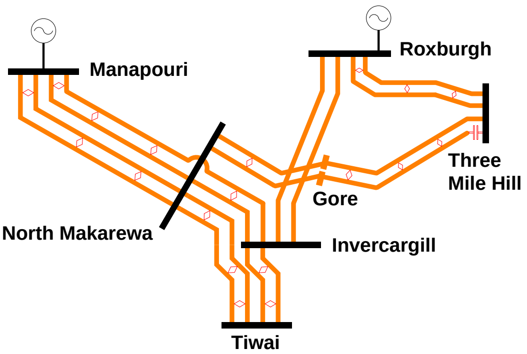
Presently, the main concern for the grid backbone in this area is the transmission capacity supplying the regional load when Manapouri generation is low and Southland demand is high. An outage of one of the two Invercargill–Roxburgh circuits may result in:

- overloading of the other Invercargill–Roxburgh circuit
- low voltages in Southland, and
- overloading of the regional 110 kV network between Gore and Roxburgh and the Roxburgh 220/110 kV transformer (see Chapter 19 for more information).

These issues are presently managed by constraining on minimum levels of generation and voltage support at Manapouri.

Figure 6-15 shows the 220 kV grid backbone circuits south of Roxburgh.

Figure 6-15: Grid backbone circuits south of Roxburgh



Circuit	Summer/Winter rating
Invercargill–Roxburgh 1 and 2	347/382 MVA
Invercargill–Manapouri 2	311/380 MVA
Invercargill–North Makarewa 1	404/457 MVA[1]
Manapouri–North Makarewa 1, 2 and 3	311/380 MVA
Invercargill–Tiwai 1 and 2	385/457 MVA[2]
North Makarewa–Tiwai 1 and 2	385/470 MVA
Roxburgh–Three Mile Hill 1 and 2	385/470 MVA
North Makarewa–Three Mile Hill 1 and 2	347/382 MVA

1. The winter rating is presently limited by a substation component limit; with this limit resolved, the winter rating will be 493 MVA.
2. The winter rating is presently limited by a substation component limit; with this limit resolved, the winter rating will be 470 MVA.

Approved projects

The Lower South Island Reliability Grid Upgrade Plan is a suite of projects to increase the grid backbone transmission capacity for power flow south from Roxburgh.

Projects to remove the constraint on the grid backbone caused by the regional 110 kV grid include (see Chapter 19 for more information):

- replacing the Roxburgh 220/110 kV transformer with a higher rated transformer in November 2012 (this will slightly ease, but not remove, the existing constraints), and
- providing a 220/110 kV connection at Gore, and reconfigure the 110 kV network in 2014 (this will provide a measureable increase in south transmission capacity).

There is also an approved project to further increase the south transmission capacity by installing a series capacitor on one of the two North Makarewa–Three Mile Hill circuits. The timing for this series capacitor will be reviewed in 2013, to optimise the timing of the upgrade.

System condition 1 (north flow)

This system condition tests power flowing north to Roxburgh:

- maximum South Island generation
- off peak South Island load (approximately 62% of island peak)
- maximum HVDC north transfer of 1,400 MW

There are no issues with the transmission capacity south of Roxburgh during north power flow for the forecast period.

System condition 2 (south flow)

This system condition tests power flowing south of Roxburgh during periods of low generation, particularly at Manapouri. To avoid overloading of the grid backbone (after the Lower South Island Reliability upgrades are completed) requires increased minimum generation in the Southland area as the load in the area increases. In 2027, approximately 350 MW of generation is required (principally from Manapouri) to avoid overloading of the grid backbone circuits supplying the Southland load.

Impact of Generation scenarios

The five generation scenarios described in Chapter 5 have the following impacts on the circuits south of Roxburgh.

Generation scenario 4 (‘coal’) connects new generation at North Makarewa (240 MW wind in 2018, 400 MW peak thermal in 2025). This will cause the Invercargill–North Makarewa circuit to overload, even with all circuits in service.

Connecting new generation to a North Makarewa–Gore–Three Mile Hill circuit may cause the circuit to overload.

There are no other grid backbone issues with additional generation (although all generation scenarios have 110 kV regional grid issues, see Chapter 19).

Any additional generation will assist in managing the power system during periods of low generation.

Outages

The transmission capacity is reduced during outages, which will constrain the minimum and maximum generation in the Otago-Southland area.

Resolving projects

The above issues are emerging late in the forecast period.

Transmission solutions to prevent overloading of the Invercargill–North Makarewa circuit include a combination of:

- reconfiguring the grid by bussing the Invercargill–Manapouri circuit at North Makarewa
- thermally upgrading the Invercargill–North Makarewa circuit(s), possibly combined with variable line ratings, and/or
- reconductoring the Invercargill–North Makarewa circuits.

Transmission solutions to prevent overloading of the North Makarewa–Gore–Three Mile Hill circuit include:

- a protection scheme to automatically reduce generation if the circuit overloads

- a thermal upgrade of the circuits, combined with variable line rating and/or
- a reconductor of (part of) the circuit.

Any further increase in south transmission capacity following completion of the Lower South Island Reliability projects will require a new transmission line. The present load forecasts do not indicate the need for a new transmission line.

The low voltage during high levels of south transmission can be addressed by:

- increasing the rating of the existing North Makarewa capacitors from 50 Mvar to 75 Mvar[28]
- additional capacitors
- operating Manapouri generators at 0 MW to provide voltage support.

[28] The two existing 50 Mvar capacitors at North Makarewa are designed to be easily upgraded to 75 Mvar.

6.7 HVDC link overview

The High Voltage Direct Current (HVDC) link connects the North and South Islands. For the North Island, the HVDC link provides access to the South Island's large hydro generation capacity, which may be important for the North Island in peak winter periods. For the South Island, the HVDC link provides access to the North Island's gas and coal generation, which is important for the South Island during dry periods.

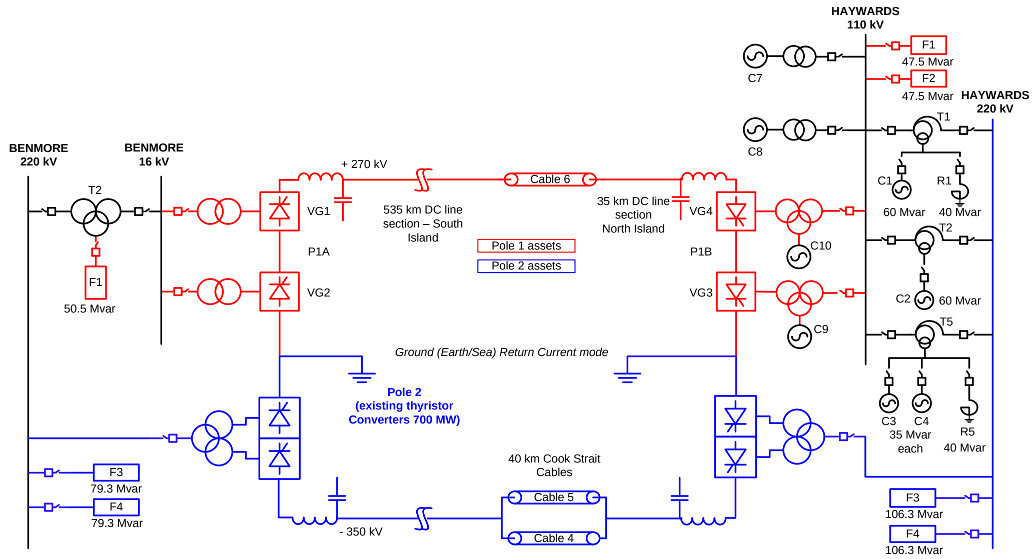
Without the HVDC link, more generation in both the North and South Islands would be needed. In addition, the HVDC link is essential for the electricity market as it allows generators in the North and South Islands to compete, putting downward pressure on prices and minimising the need to invest in expensive new generating stations. The HVDC link also plays an important part in allowing renewable energy sources to be managed between the two islands.

6.7.1 Existing HVDC link configuration

Figure 6-16 shows a simplified schematic of the existing HVDC link, which comprises:

- a mercury arc converter (Pole 1), with a converter station at Benmore in the South Island and Haywards in the North Island
- a thyristor converter (Pole 2), with a converter station at Benmore in the South Island and Haywards in the North Island
- protection and control systems at Benmore and Haywards
- a 350 kV bipolar transmission line, 534 km long from Benmore to Fighting Bay on the shore of Cook Strait in the South Island and 37 km long from Haywards to Oteranga Bay on the shore of Cook Strait in the North Island
- three 350 kV undersea 40 km cables, with cable terminal stations at Fighting Bay and Oteranga Bay, and
- a land electrode at Bog Roy near Benmore in the South Island and a shore electrode at Te Hikowhenua near Haywards in the North Island.

Figure 6-16: Existing HVDC link



6.7.2 Future HVDC link configuration

Figure 6-17 shows a simplified schematic of the HVDC link as it will be following the completion of the Pole 3 project in 2012/13. The Pole 3 project will replace the Pole 1 mercury arc converters with new converters similar to the existing Pole 2 converters, and connected to the 220 kV buses at Haywards and Benmore. The work includes:

- new thyristor based converters at Benmore and Haywards, including the associated converter transformers and DC smoothing reactors
- new 220 kV AC filters at Benmore and Haywards
- replacement of the existing 110 kV AC filters at Haywards
- refurbishment of all synchronous condensers at Haywards and new 110/11 kV transformers for four of the condensers, and
- replacement of HVDC protection and controls.

Figure 6-17: Pole 2/Pole 3 HVDC link

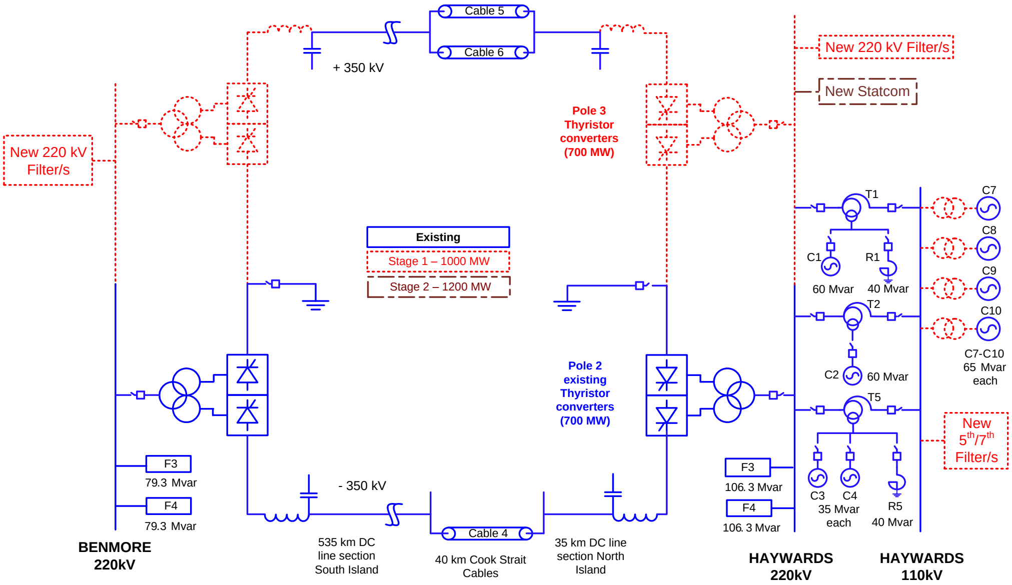
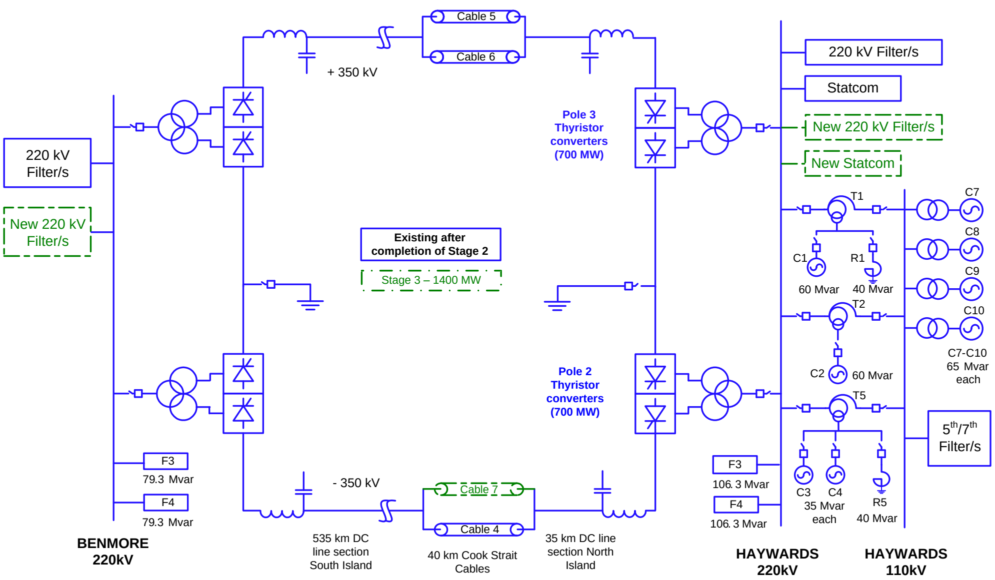


Figure 6-18 shows a simplified diagram for a possible further expansion of the HVDC link to 1,400 MW north capacity following completion of the Pole 3 project. This would involve the installation of:

- one additional submarine cable
- additional filters at both Benmore and Haywards, and
- additional dynamic reactive support at Haywards.

Figure 6-18: Possible future HVDC link



6.8 HVDC link issues and project options

6.8.1 HVDC link capacity

In 1992, the HVDC link capacity was 1,240 MW, with a Pole 1 capacity of 640 MW and a Pole 2 capacity of 700 MW.

The HVDC link capacity is now significantly lower. Pole 1 is available for only limited operation, including north transfer only of between 130 MW and 200 MW. Pole 2 is normally available, with a maximum transfer of 700 MW. However, with only Pole 2 in operation, the HVDC link transfer is dependent on the reserve cover available, which significantly reduces the maximum practical transfer limit.

It is economic to restore the HVDC link capacity.

The Pole 3 project, to replace Pole 1, will provide an HVDC link capacity of 1,000 MW (north and south power flow), with a possible increase to 1,200 MW in 2014. It will not always be possible to use the full capacity of the HVDC link. Power transfer between the North and South Islands may be limited by the availability of instantaneous reserves and the capacity of the North and South Island transmission networks (refer to Sections 6.4 and 6.6 respectively).

The other sections of the Annual Planning Report assume that the Pole 3 project to replace Pole 1 is completed in 2012/13.

6.8.2 State of existing equipment

Pole 1

Pole 1 was commissioned in 1965. Half of the original Pole 1 was decommissioned in December 2009.

The remaining half of Pole 1 is available under limited conditions: for normal operation, in response to Grid emergencies, and for testing. The conditions include north transfer between 130 MW and 200 MW, with automatic controls unavailable (except frequency modulation). Other conditions include a limit on the number of starts, minimum operating time per start and cumulative operating time[29].

When Pole 1 is not operating, HVDC bipole operation is not available. Without bipole operation, the HVDC is in monopolar operation, which results in:

- reduced HVDC capacity (one pole rather than two poles in operation)
- increased reserve cover from generation and load required for a Pole trip, and
- ground (sea/earth) return current.

With regard to the reserve cover required, in bipole operation should one pole fail then the remaining pole can increase its power transfer, which provides some self cover. This could be partial or full load cover depending on pre-fault power flow of the remaining pole. There is no self cover possible in monopolar operation with only HVDC Pole 2 in service.

The maximum possible transfer with only Pole 2 in service is 700 MW. However, the normal link transfer is dependent on the reserve cover available. This significantly reduces the practical transfer limit at most times.

Also, a planned or unplanned outage under monopolar operation decouples the two islands, reducing the generation available to both islands and introducing price separation (or reduced competition).

[29] For further details of the HVDC Pole 1 offer, see http://www.transpower.co.nz/grid-owner-notices.

With regard to ground (sea/earth) return current, in monopolar operation all of the HVDC current flows in the ground.[30] To date, we have not had any problems with ground return current, other than wear on the sea/earth electrodes.

The effect of the restricted operating conditions for Pole 1 highlights the need for its replacement.

Pole 2

Pole 2 was commissioned in 1991, with a design life of 35 years for the main circuit equipment, although most of the equipment is expected to last longer. Some main circuit equipment is also common to Pole 1 and Pole 2 (neutral bus and electrode line equipment), which was also installed in the early 1990s.

The nominal rating of Pole 2 is 560 MW, with a continuous overload of 700 MW. The continuous overload has proved very beneficial for limiting reserve requirements and managing emergency conditions.

HVDC controls

All the HVDC Pole 1 and bipole controls and protections date from when Pole 2 was installed in the early 1990's. These digital control systems face obsolescence because the lifetime of control systems (about 15-20 years) is shorter than that of the main circuit equipment, thus requiring at least one full replacement within the lifetime of the HVDC converter equipment.

HVDC transmission lines

The transmission line was originally built for +/- 250 kV 1200 A operation (600 MW bipole operation). During the hybrid link upgrade, the line was re-insulated to operate at 350 kV and thermally upgraded for maximum continuous current of 2000 A. Therefore, the line is capable of 700 MW per pole or 1,400 MW bipole operation.

Most of the conductor on the line in the North Island is nearing the end of its serviceable life, based on condition assessment. Most of the conductor in the South Island is expected to have a remaining service life of several decades.

About 100 of the 1,530 towers in the South Island need to be replaced to correct a number of conductor clearance and tower strength issues as part of the line maintenance work.

HVDC submarine cables

Three cables (each rated 500 MW at 350 kV) were installed as part of the Hybrid DC link upgrade project in the early 1990s.

Between 1991 and 2004, the three cables had performed well with no major issues or failures. In October 2004, a cable failed and was out of service for six months while repairs were carried out. It was fortunate that this fault was in shallow water in Oteranga Bay so it could be repaired using a locally available barge, with sufficient time to mobilise a repair before the limited weather window in February/March ended.

While the cause of failure is difficult to establish, and the balance of probabilities indicates that it is likely to be a localised problem, it is also possible that there is a latent design weakness or manufacturing defect which could result in another fault in the cable, or even one of the other cables.

[30] In balanced bipole operation, the dc current in both poles is equal and opposite (within an accuracy of about 4 amps). Thus the current in one Pole returns through the other Pole, and the 4 amps of unbalanced current flows in the ground (sea/earth) electrode.

There is a Cable Protection Zone (CPZ) to exclude external activities which might damage the cables. These cables are also under constant marine patrol preventing fishing and trawling activities within the CPZ. Regular Remote Operated Vehicle (ROV) surveys are also undertaken to monitor the external condition of the cable and the environmental factors affecting the cables.

The cables' design and the CPZ help ensure the cables will achieve their 40 year design life. However, sea conditions and seabed movement makes Cook Strait one of the most aggressive locations for submarine cables in the world. The abrasion-corrosion conditions in Cook Strait are understood and mechanical deterioration is likely to be the determinant factor in determining the life expectancy of the cables.

HVDC electrodes

A bipolar HVDC link operating with balanced current in both poles has only a small amount of residual ground current. In unbalanced bipolar operation, or in monopolar operation, a return current path needs to be provided.

The return current path is via the earth (ground), which requires a land electrode at Bog Roy, for Benmore, and a shore electrode at Te Hikowhenua, for Haywards station. These electrodes are designed for continuous operation at 2000 amps. This corresponds to 700 MW monopolar operation at 350 kV DC. It is capable of operating at 2400 A for intermittent (few hours at a time) operation.

Monopolar operation depends on the availability and integrity of the electrodes to ensure safe operation of the link. The long term impact of operating in continuous monopolar operation at high power levels is not readily available. Since the partial decommissioning and restricted operation of Pole 1, monopolar operation of the HVDC link has been its normal operating mode. We and our contractors carry out regular maintenance work to ensure the integrity of these electrodes, and the electrodes remain within their design limits.

Synchronous condensers

There are eight synchronous condensers at Haywards, providing reactive support and improving system strength to enable stable operation of the HVDC link. The number of synchronous condensers that need to be in service depends on the HVDC bipole power transfer, if all other system conditions are equal.

Four condensers are connected to the tertiary windings of the 220/110/11 kV interconnecting transformers. Two condensers are connected through recently installed new 110/11 kV transformers. The other two condensers are connected to the tertiary windings of the Pole 1 converter transformers. The Pole 1 transformers are nearing the end of their reliable economic life.

The condensers were installed between 1955 and 1965 and are of very robust design and construction. Good international practice is for major overhaul and invasive maintenance every 15-20 years, which was last done in 1989-1992. In addition, much of the auxiliary equipment either no longer meets modern practice or is nearing the end of its reliable economic life.

6.8.3 Approved HVDC link projects (Stage 1 and 2)

The HVDC Pole 3 project is an approved project, presently under construction, to increase the HVDC link capacity (refer to Section 6.8.1) and address equipment issues (refer to section 6.8.2). The Pole 3 project is in two stages:

- Stage 1 provides an HVDC link capacity of 1,000 MW, and
- Stage 2 provides an HVDC link capacity of 1,200 MW.

Figure 6-17 (in Section 6.7.2) shows a simplified diagram for the two stages.

The connection and commissioning of Pole 3 has the potential to significantly affect the operation of the power system and the electricity market. An industry group has been established to coordinate outage and commissioning activities to minimise these impacts.

HVDC converters (Stage 1 – 1,000 MW)

Pole 3 will have a nominal operating DC voltage of 350 kV and a continuous current rating of 2000 A, to give a 700 MW converter. The upper limit on the voltage is set by the existing line design and cable ratings. The maximum nominal current is limited by the line rating and the continuous rating of the new Pole 3 equipment.

A 30 minute overload capacity of 1,000 MW for Pole 3 reduces the overall system reserve requirements.

HVDC transfer north up to 1,000 MW in balanced 500/500 MW bipole operation is possible.

Only three cables are available, which limits the self cover of the HVDC for a pole trip:

- Pole 3 will have two cables connected, so the short-term 1,000 MW capacity of Pole 3 is matched by the 1,000 MW cable capacity, but may be limited by the steady-state 700 MW rating of the transmission line. Pole 3 will provide a minimum cover up to 700 MW for a failure of Pole 2.
- Pole 2 will have one cable connected, so the 700 MW capacity of Pole 2 will be limited by the 500 MW rating of the cable. Pole 2 will provide cover up to 500 MW for a failure of Pole 3.

As discussed in Section 6.8.1, the south transfer capability is limited by the capacity of the AC network in the North and South Islands, and varies significantly with the system demand in the Wellington region because of the AC system limitation. The HVDC controls will apply a maximum south transfer limit of 750 MW to represent this AC system limitation with all equipment in service and at a time of minimum system demand. The south transfer capability will reduce below this value as the demand increases (and during equipment outages).

110 kV filters at Haywards

The 110 kV connected filters at Haywards, installed as part of the original HVDC Link in the mid 1960s, will be replaced by $5^{th}/7^{th}$ harmonic filters.

Synchronous condensers at Haywards

The eight existing condensers will be retained and refurbished. The two condensers that are connected to the Pole 1 mercury arc valve converter transformers will be reconnected to the 110 kV busbars with new transformers after Pole 1 is decommissioned.

Pole 2 and Bipole protection and control

The Pole 2 and Bipole control systems will be replaced with identical technology to that of new Pole 3. The Pole 2 valve firing controls will be replaced as part of the new Pole 2 control system, and will interface to the existing valve based electronics (which will be retained) at the thyristors.

The new control system will be very flexible. It will monitor and control the HVDC transfer to manage system conditions at Haywards and Benmore and on the AC network at Haywards. The flexibility of the new control system will provide options to modify it, allowing the AC network to operate above the n-1 limit by relying on the HVDC control system to prevent post-contingency overloads.

Haywards STATCOM (Stage 2 – 1,200 MW)

In addition to the existing synchronous condensers, additional dynamic reactive power capacity will be required to achieve HVDC capacity greater than 1,000 MW, driven by two major functional requirements to:

- provide reactive support and improve voltage stability
- limit excessive transient or temporary overvoltage (TOV) following a bipole trip.

A STATCOM with a substantial overload rating will provide the necessary dynamic reactive support for HVDC capacity of 1,200 MW. The STATCOM has a nominal rating of +60/-60 Mvar and a short-term rating which is expected to be a minimum of +100/-180 Mvar.

HVDC north transfer up to 1,200 MW is possible with unbalanced 700/500 MW operation of Pole 3/Pole 2.

Only three cables are available, which limits the self-cover of the HVDC for a pole trip as described for Stage 1.

As for Stage 1, the south transfer capability is limited by the capacity of the AC network and will vary significantly with the system demand in the Wellington region. The HVDC controls at Stage 2 will limit the maximum south transfer to 850 MW with all equipment in service and at a time of minimum system demand. The increase from Stage 1 is due to the additional reactive support provided by the STATCOM. The south transfer capability will reduce below this value as the demand increases (and during equipment outages).

HVDC line rating

Each of the poles on the HVDC line has a steady state rating of 700 MW, whereas Pole 3 will have a minimum short-term rating of 1,000 MW for 30 minutes. The short-term rating of the line depends on its pre-contingency loading and ambient air temperature. At times, the full short-term rating of Pole 3 may be restricted by the rating of the line.

6.8.4 Further HVDC developments

HVDC link expansion to 1,400 MW

Following the Pole 3 project, the HVDC Link can be further expanded to 1,400 MW north transfer capacity with the installation of:

- one additional submarine cable
- additional filters at both Benmore and Haywards, and
- additional dynamic reactive support at Haywards.

Figure 6-18 (in Section 6.7.2) shows a simplified diagram for this possible upgrade.

The HVDC controls will limit the maximum south transfer to 950 MW with all equipment in service and at a time of minimum system demand. The increase from Stage 2 is due to the additional reactive support at Haywards. The south transfer capability will reduce below this value as the demand increases (and during equipment outages)

When planning for the additional cable, the condition and risks associated with the existing cables will also be reviewed and the need for a spare (fifth) cable will be assessed.

The timing for this possible upgrade will be assessed following completion of the Pole 3 project. The earliest anticipated date for expansion to 1,400 MW is presently 2017 and we anticipate seeking approval from the Commission in 2014. This would be a major capex proposal and our project reference is HVDC-TRAN-DEV-03.

We anticipate that a capacity increase to 1,400 MW will provide sufficient capacity to enable diversity of generation in the North and South Islands for the foreseeable future.

HVDC line rating

The HVDC line's capacity could be increased to allow the unconstrained use of the converters' short-term overload rating for all operating conditions. We will monitor the use of the HVDC link to determine if and when an investigation for an upgrade of the HVDC line may be required. This is a possible major capex proposal and we anticipate seeking approval for this project at a date to be advised. Our project reference is HVDC-TRAN-DEV-02.