TRANSPOWER

Lower South Island Reliability Investment Proposal

Attachment C
Power System Analysis

May 2010

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001	LSI Reliability Investment Proposal – Attachment C Power System Analysis	May 2010

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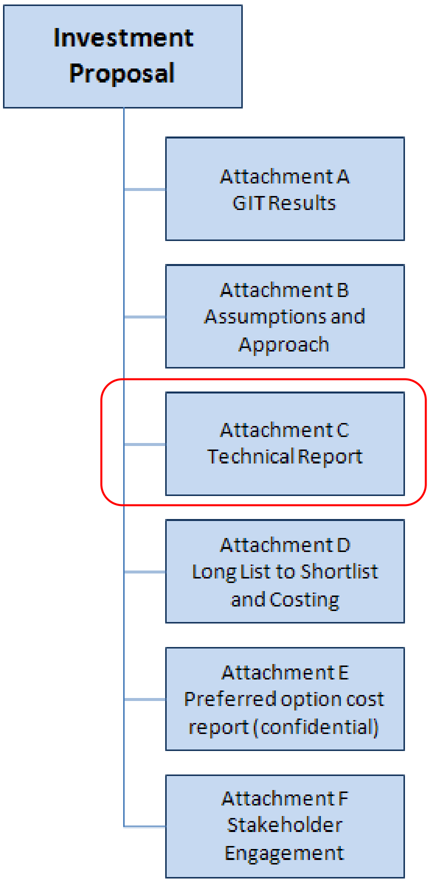
1 Introduction

This report presents the results of the power system analysis carried out by Transpower to determine and assess the upgrade options to increase the transmission grid capacity south of Roxburgh.

This report includes a constraint study of the existing grid and assessment of the upgrade options that are required to provide grid reliability in accordance with the Electricity Governance Rules (EGRs).

2 Structure of the document

This document forms part of the Proposal. The documentation is structured according to the following diagram:



3 Scope of the study

The scope of the analysis considers the transmission grid south of Roxburgh where the 220 kV network consists of the following lines:

- Invercargill–Roxburgh A and B
- Manapouri–Tiwai A
- Invercargill–Manapouri A
- Invercargill–Tiwai A
- Roxburgh–Three Mile Hill A
- North Makarewa–Three Mile Hill A

and the parallel regional 110 kV transmission network which consists of the following lines:

- Halfway Bush–Roxburgh A
- Gore–Roxburgh A
- Gore–Halfway Bush A (with deviation to Balclutha)
- Gore–Invercargill A (with deviation to Brydone)

The scope of the study is to identify the grid constraints on the transmission system south of Roxburgh and assess the required upgrade options to ensure the transmission grid (south of Roxburgh) meets Grid Reliability Standard (GRS).

4 Background to Lower South Island Reliability

4.1 Existing System Configuration

The Lower South Island (LSI) or Otago-Southland region is shown geographically in Figure 4-1 and schematically in Figure 4-2. The region for the scope of this study is marked south of the dotted line, i.e. south of Roxburgh.

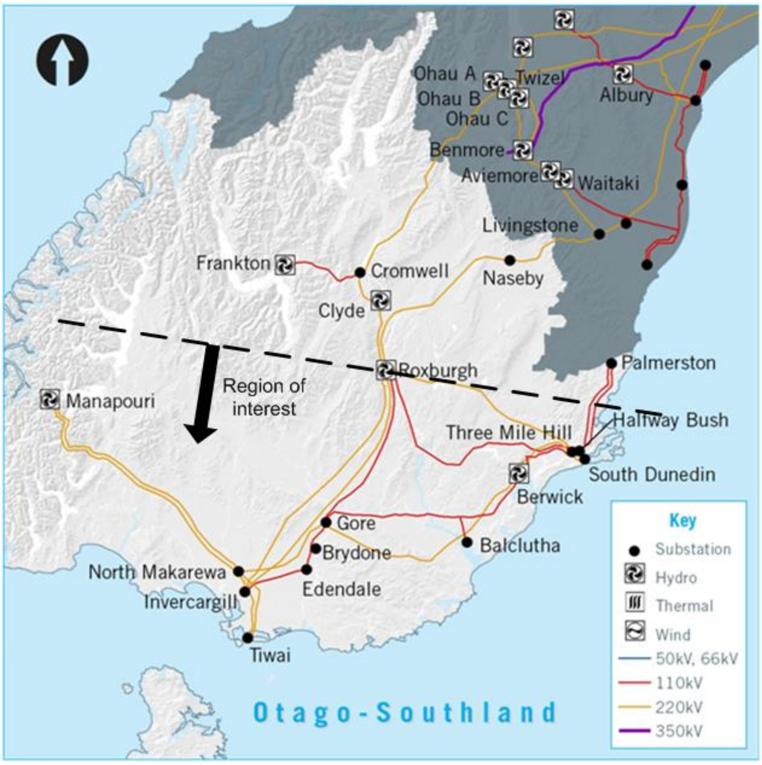


Figure 4-1: Lower South Island region (Otago-Southland Region)

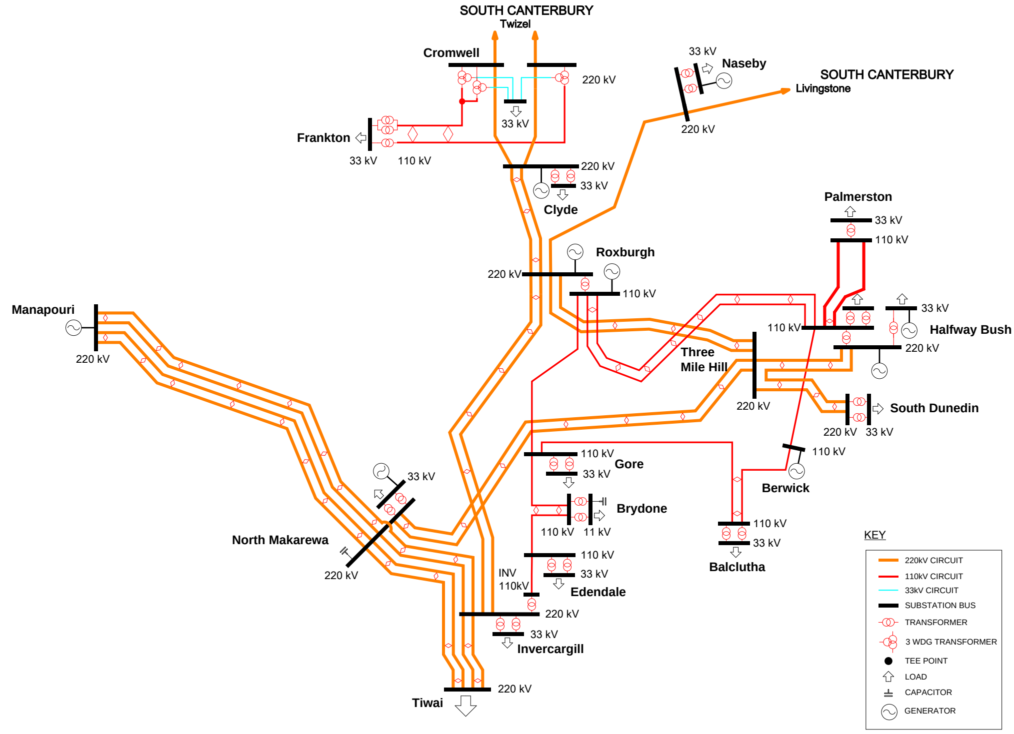


Figure 4-2: Transmission network south of Roxburgh

Table 4-1 shows the key parameters of the transmission network south of Roxburgh.

Table 4-1: Existing circuit ratings south of Roxburgh

Circuit Name	Winter kA(1)	Summer kA(1)	Winter MVA(1)	Summer MVA(1)	Conductor Type (2)	Bundle Count(2)	Sag Temp.
Balclutha -Berwick	0.325	0.266	62	51	Copper	Simplex	50^{0}C
Balclutha-Gore	0.325	0.266	62	51	Copper	Simplex	50^{0}C
Brydone-Edendale	0.325	0.266	62	51	Copper	Simplex	50^{0}C
Brydone-Gore	0.325	0.266	62	51	Copper	Simplex	50^{0}C
Berwick-Halfway Bush	0.325	0.266	62	51	Copper	Simplex	50^{0}C
Edendale-Invercargill	0.325	0.266	62	51	Copper	Simplex	50^{0}C
Gore-Roxburgh	0.406	0.333	77	63	Wolf	Simplex	50^{0}C
Halfway Bush-Palmerston	0.313	0.256	60	49	Copper	Simplex	50^{0}C
Halfway Bush-Roxburgh	0.406	0.333	77	63	Wolf	Simplex	50^{0}C
Halfway Bush-South Dunedin	0.971	0.875	370	333	Zebra	Simplex	71.10C
Halfway Bush-Three Mile Hill	0.971	0.875	370	333	Zebra	Simplex	71.1^{0}C
Invercargill-Manapouri	0.997	0.818	380	312	Goat	Duplex	50^{0}C
Invercargill-North Makarewa	1.293	1.06	493	404	Goat	Duplex	50^{0}C
Invercargill-Roxburgh	1.003	0.911	382	347	Zebra	Simplex	75^{0}C
Invercargill-Tiwai	1.293	1.06	493	404	Goat	Duplex	50^{0}C
Manapouri-North Makarewa	0.997	0.818	380	312	Goat	Duplex	50^{0}C
North Makarewa-Three Mile Hill	1.003	0.911	382	347	Zebra	Simplex	75^{0}C
North Makarewa-Tiwai	1.233	1.011	470	385	Goat	Duplex	50^{0}C
Roxburgh-Three Mile Hill	1.233	1.011	470	385	Zebra	Duplex	50^{0}C
South Dunedin-Three Mile Hill	0.971	0.875	370	333	Zebra	Simplex	71.1^{0}C

(1) Rating of lowest rating conductor
(2) Longest section, if more than one section is existing

4.2 The need for increased capacity within the region south of Roxburgh

There are two issues that drive the need for upgrading the transmission grid south of Roxburgh:

Power transfer limitation on 220 kV and 110 kV network

During times of low Otago-Southland generation, part of the regional load is supplied from the north. Power transfer from Roxburgh to south is constrained by the need to avoid overloading the Gore – Roxburgh 110 kV circuit for the loss of an Invercargill – Roxburgh 220 kV circuit. The next constraint is the need to avoid overloading an Invercargill – Roxburgh 220 kV circuit for the loss of the parallel Invercargill – Roxburgh 220 kV circuit.

Power supply limitation on 110 kV network

The 110 kV transmission network within Otago-Southland region comprises low capacity circuits. Load limits are required on the Grid Exit Points supplied from the 110 kV network in Southland to avoid overloading of assets. The 110 kV network also encounters capacity and voltage issues during various 110 kV circuit outages. A planned outage of 110 kV circuits often requires load management, regional generation being available during the outage and grid reconfiguration (splitting the 110 kV network to avoid through transmission which places some loads on N security for the duration of the outage). It is increasingly difficult to schedule outages of the 110 kV as the windows where load is low enough to take the outage are decreasing as load continues to grow in the 110 kV network.

5 Planning Methodology and Assumptions

The need to upgrade the transmission grid south of Roxburgh is twofold:

- Alleviate constraints on the 220 kV network where the grid is required to meet N-1 deterministic criteria in accordance with the existing EGR's
- Alleviate constraints on the 110 kV network where both N and deterministic (N-1) criterion will be considered. Transpower will use a cost-benefit based economic criterion for determining the most efficient investment and the investment "need date".

5.1 Methodology

For the core grid, the grid is required to meet N-1 deterministic criteria in accordance with the Grid Reliability Standard in the Electricity Governance Rules. The transmission grid must be in a satisfactory state following an N-1 event. Therefore, the power system analysis is required to assess the grid's ability in meeting N-1 security (both thermal and voltage stability).

For the non-core grid part of the network, the power system analysis looks at the upgrade options to address transmission constraints for N security as well as the additional upgrade options required to address transmission constraints for N-1 security.

The methodology used to analyse the transmission grid is as follows:

- Determine the transmission grid constraints based on the generation and demand assumptions for the horizon years.
- Establish development plans to meet demand growth and alleviate transmission grid constraints (thermal and voltage stability) from the long list of options.
- Constraint equations are calculated for the existing grid and proposed upgrade options as an input to economic analysis.

5.1.1 Generation Assumption

Table 5-1 defines the generation dispatch used in the power system analysis.

Table 5-1: Generation dispatch assumptions

Generators	Generation Dispatch (MW)
Clyde	432 MW
Manapouri	220/275 MW (pre-/post-contingency)
Roxburgh 220 kV	220 MW
Roxburgh 11 0 kV	40/0 MW (pre-/post- replacement of Roxburgh T10)
Waipori	25 MW
White Hill	0 MW

The constraints on the transmission grid are largely dependent on Otago-Southland generation, in particular from Manapouri and Roxburgh 110 kV generation.

The minimum generation from Manapouri is 180 MW average per day with all circuits in service. This equates to 220 MW at the peak for the day and a correspondingly lower value at non-peak times so the daily average remains at 180 MW per day. However, following an outage due to a permanent fault on an Invercargill – Roxburgh circuit, the minimum Manapouri generation is 247 MW average per day. This equates to 265-275 MW at the peak for the day and a correspondingly lower value at non-peak times, allowing for a 25-15 MW operating margin.

Roxburgh is required to generate a minimum of 40 MW to meet resource consent requirements. The existing Roxburgh interconnecting transformer T10 is rated at 50 MVA. To minimise constraints needed to prevent overloading of this transformer, the minimum 40 MW of generation is produced from generators connected to the 110 kV bus. Assuming that the Roxburgh interconnecting transformer T10 is replaced with a higher capacity transformer (refer section 5.1.3), this minimum generation can be on the Roxburgh 220 kV bus, and 0 MW on the Roxburgh 110 kV bus is possible. This reduces the loading on the Gore-Roxburgh 110 kV circuit and hence minimise the constraints to prevent overloading of this circuit.

The power system analysis also assumes that:

- Generators outside the region of study (i.e. Waitaki valley generators, upper South Island generators) are generating 80-100% of their capacity
- The South Island slack bus is modelled at Benmore to represent the HVDC link
- South Island embedded generators such as Naseby and Halfway Bush are assumed to be netted off from the demand.

5.1.2 Demand Assumptions

The power system analysis uses a prudent peak demand forecast conducted by Covec as a base forecast, modified to account for customer feedbacks where appropriate.

The prudent peak demand forecast is based on a 10% POE criterion.

An After Diversity Maximum Demand (ADMD) peak forecast and power factor are applied at each grid exit point level to make up of the Southland load demand.

Appendix A of this document presents the demand forecast used at each GXP level for the power system analysis.

5.1.3 Roxburgh T10 and Invercargill T1 transformer replacement

Both the Roxburgh T10 and Invercargill T1 interconnecting transformers are programmed for replacement within five years based on transformer condition assessment. These transformers also cause and/or affect 110 kV network constraints. Therefore, the power system analysis assumes these transformers are replaced with new transformers with an appropriate MVA rating and impedance to maximise the load that can be taken from Gore.

In the analysis Roxburgh T10 is assumed to be 150 MVA with 15% impedance and Invercargill T1 is assumed to be 100 MVA with 10% impedance.

5.1.4 Summer/Winter Scenarios

The grid is constrained more during the summer period than the winter period. Therefore, the options assessment is based on summer scenarios. Winter scenarios have also been analysed to ensure upgrade options are sufficiently adequate for both summer and winter periods.

5.2 Capacity of the existing system

The constraints on the transmission grid south of Roxburgh occur when LSI generation is low (resulting in south flow from Roxburgh) with summer period being the worst scenario.

Power system analysis shows that there are several constraining circuits during N-1 condition. Circuit loading with respect to various creditable contingencies are shown below to indicate the existing grid constraints. The circuit loading under system normal is shown in Figure 5-1 for comparison.

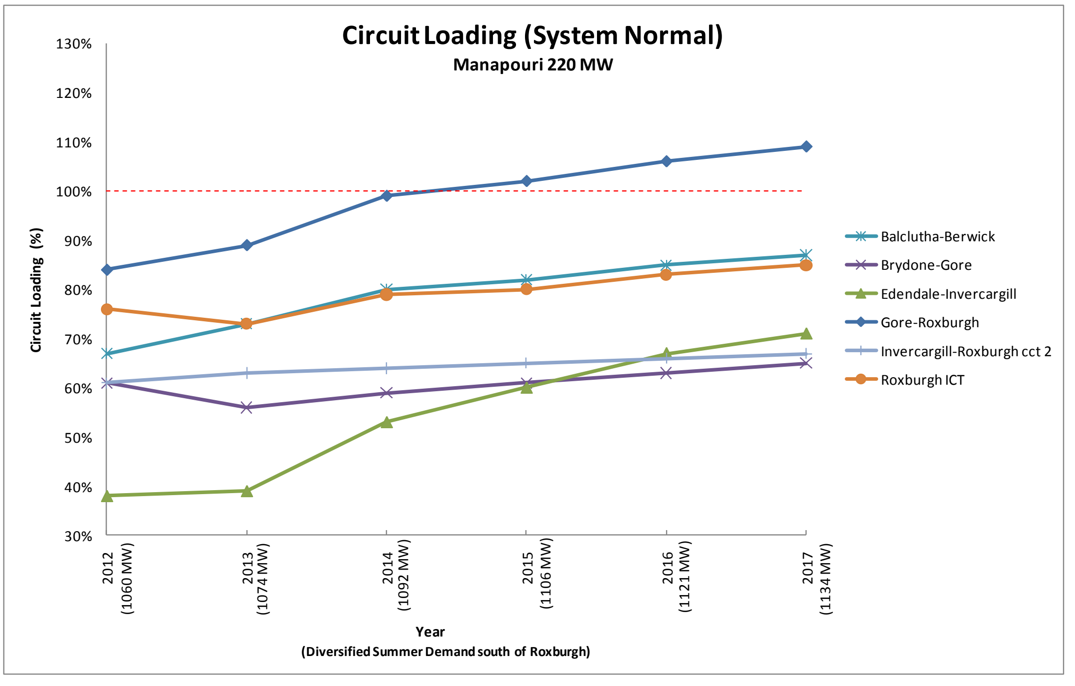


Figure 5-1: Circuit loading during system normal

Figure 5-2 shows the grid constraints with the outage of Invercargill – Roxburgh 1 or 2.

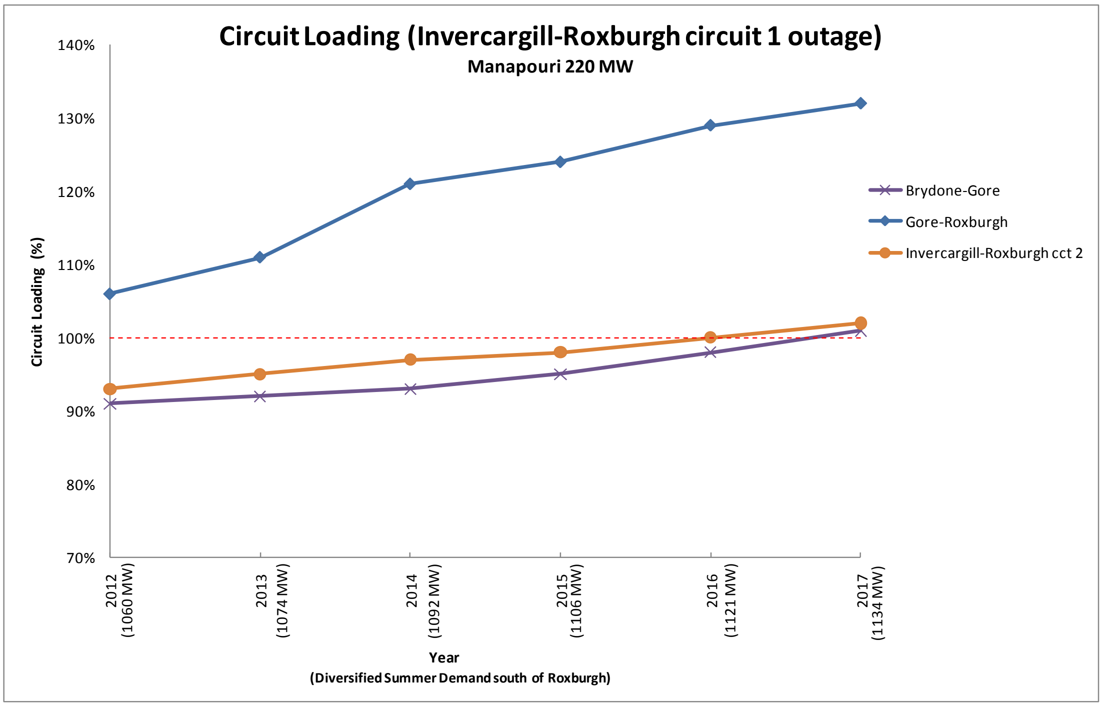


Figure 5-2: Grid constraints with the outage of Invercargill – Roxburgh 1 or 2

Figure 5-3 shows the grid constraints with the outage of Gore – Roxburgh.

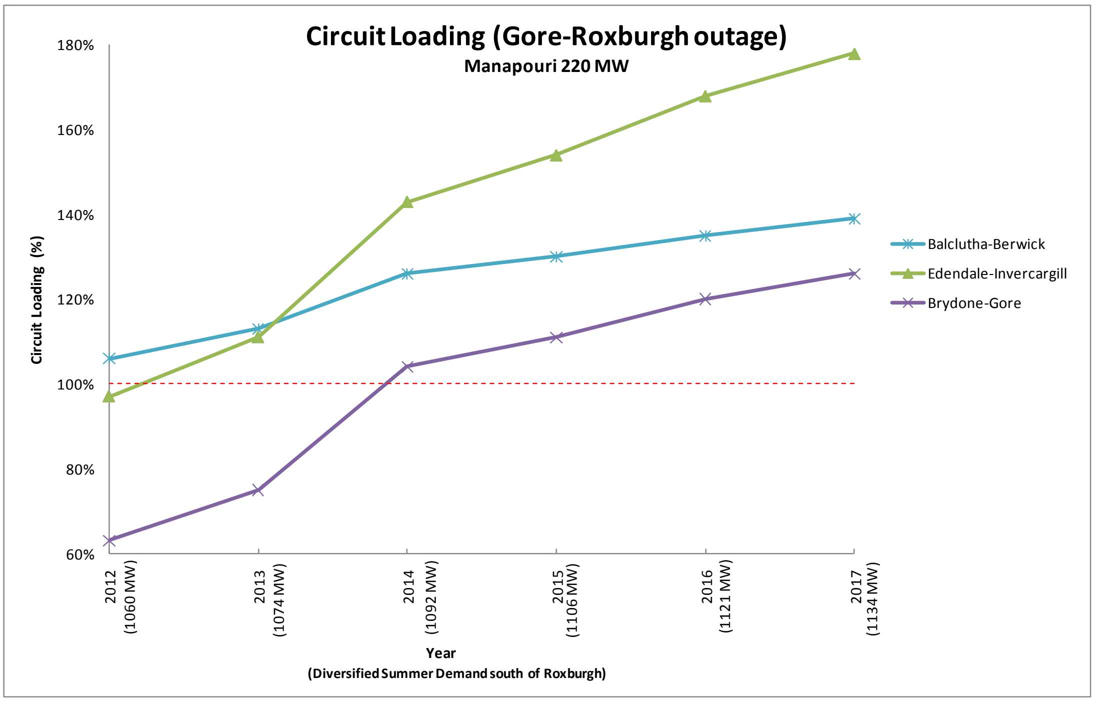


Figure 5-3: Grid constraints with the outage of Gore – Roxburgh

Figure 5-4 shows the grid constraints with the outage of Balclutha – Berwick – Halfway Bush.

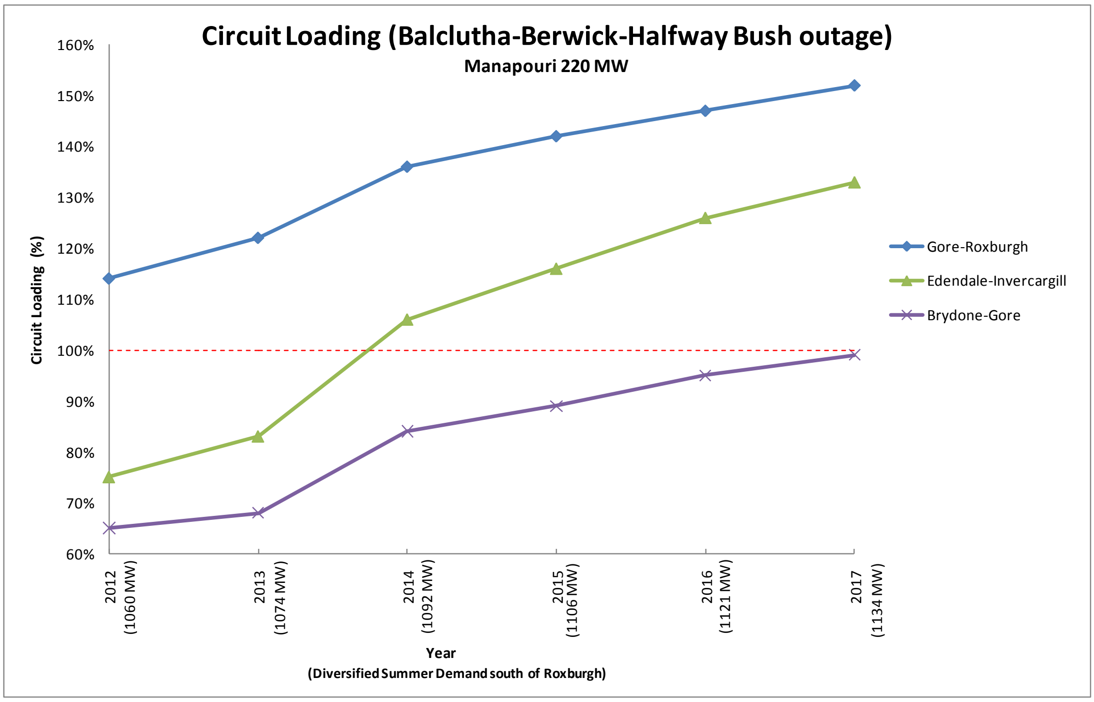


Figure 5-4: Grid constraints with the outage of Balclutha – Berwick – Halfway Bush

Figure 5-5 shows the grid constraints with the outage of Edendale - Invercargill.

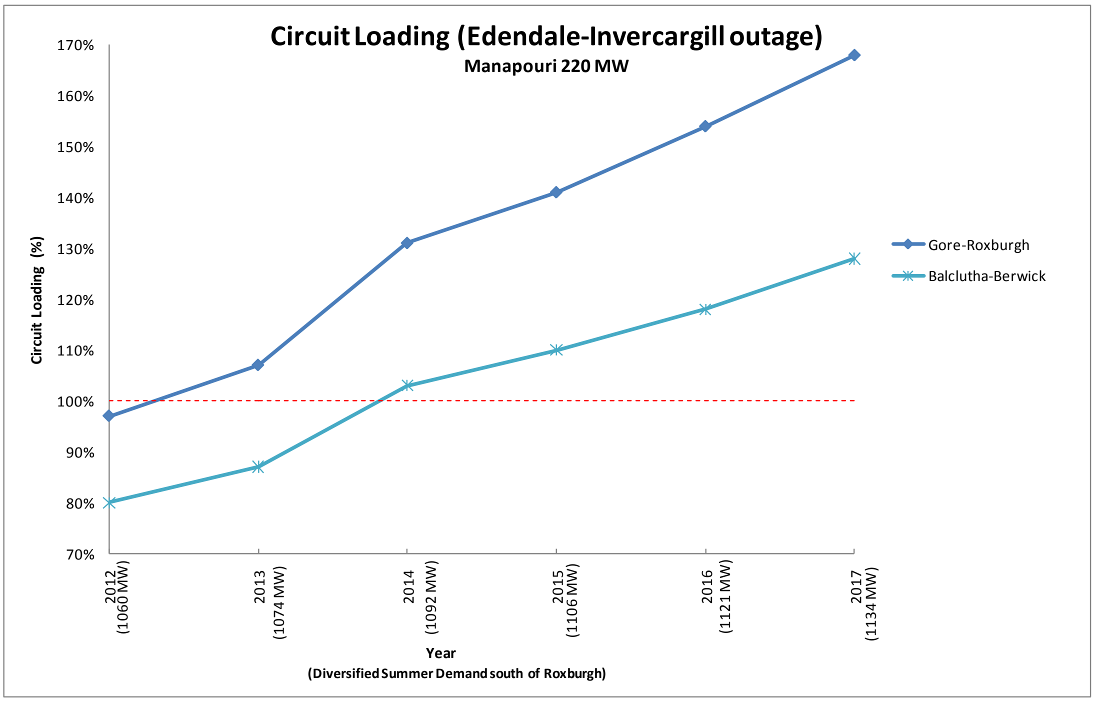


Figure 5-5: Grid constraints with the outage of Edendale – Invercargill

Figure 5-6 shows the grid constraints with the outage of Invercargill T1 transformer.

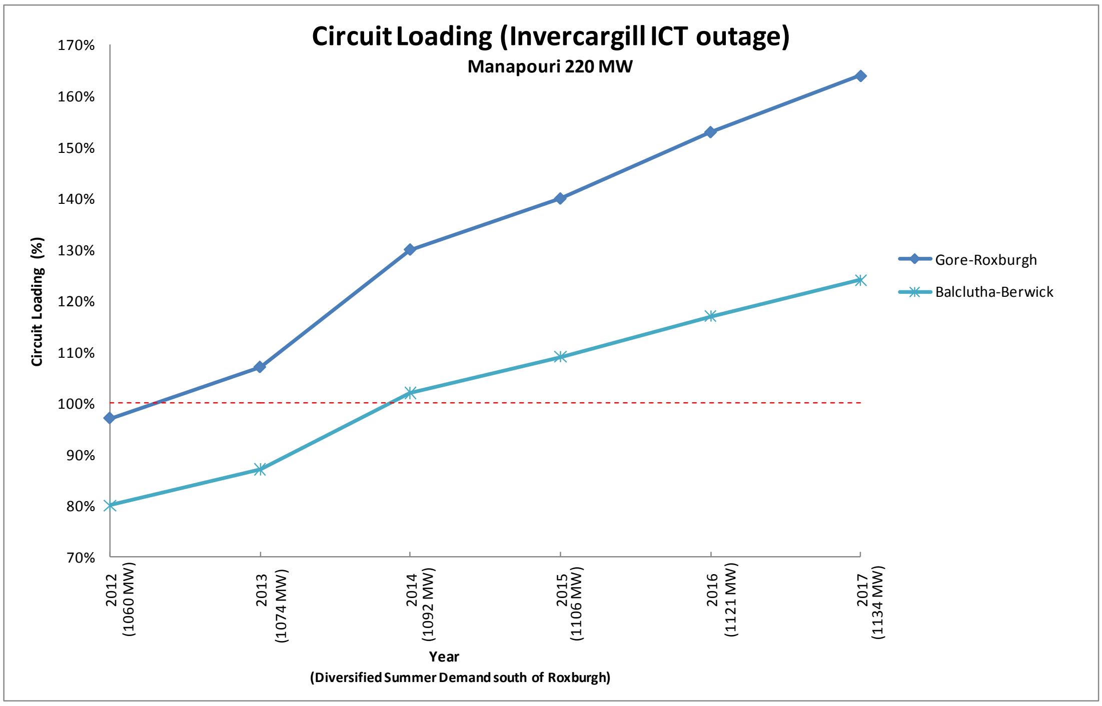


Figure 5-6: Grid constraints with the outage of Invercargill T1 transformer

Figure 5-7 shows the grid constraints with the outage of Roxburgh T10.

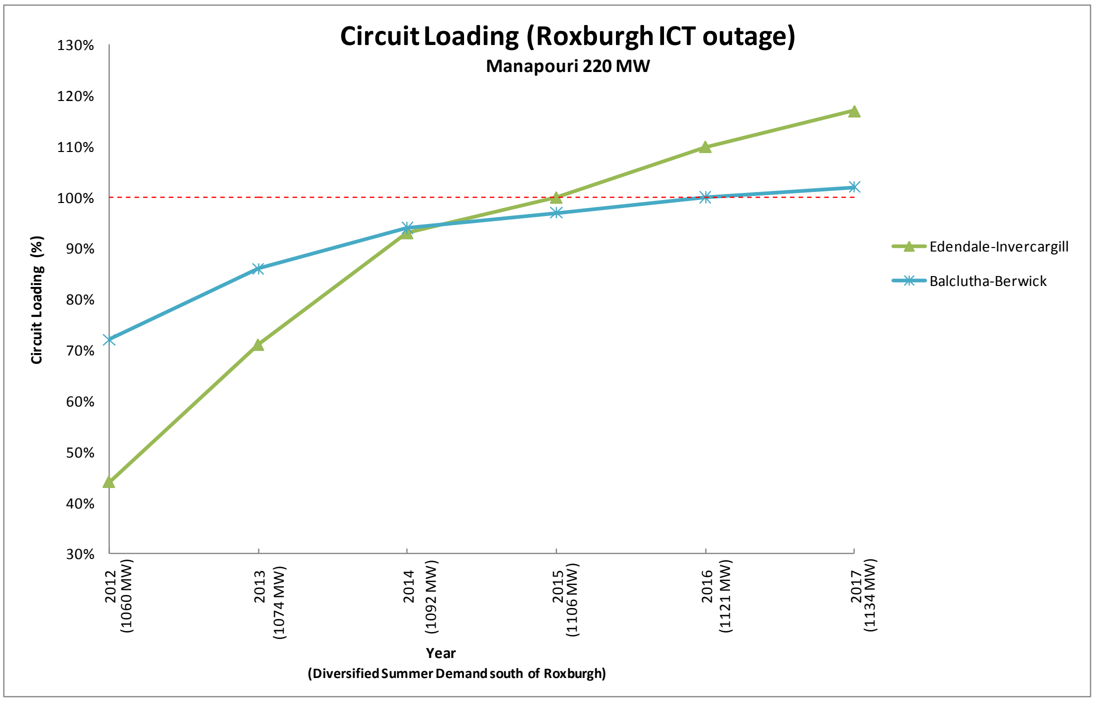


Figure 5-7: Grid constraints with the outage of Roxburgh T10

Figure 5-8 shows the grid constraints with the outage of Balclutha - Gore.

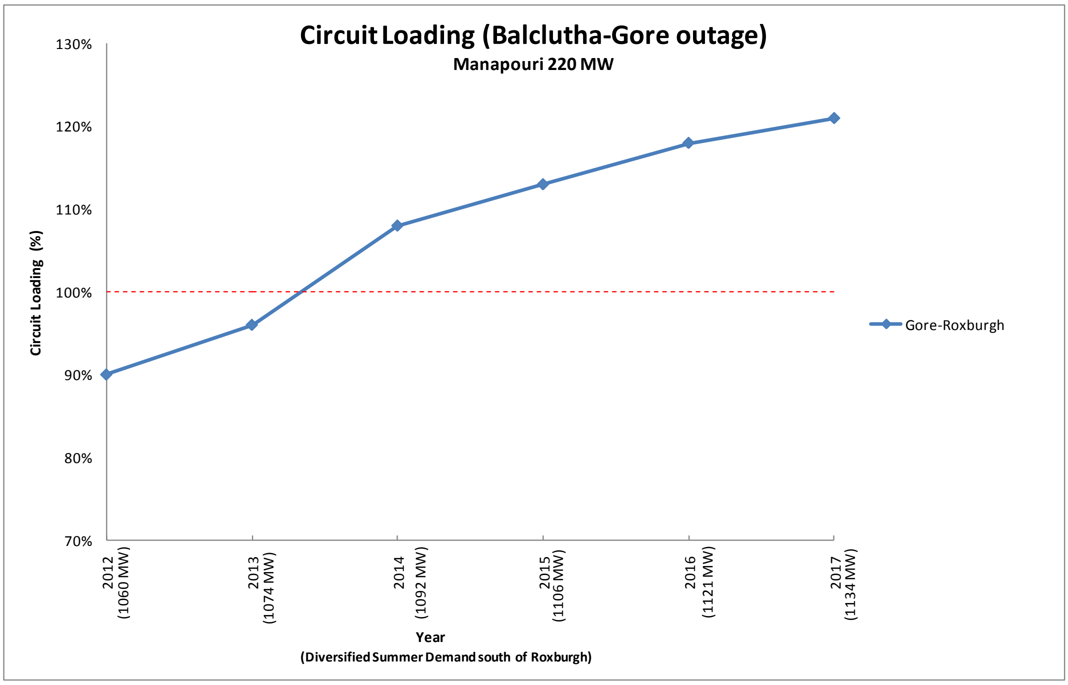


Figure 5-8: Grid constraints with the outage of Balclutha - Gore.

Figure 5-9 shows the grid constraints with the outage of Halfway Bush T4 transformer.

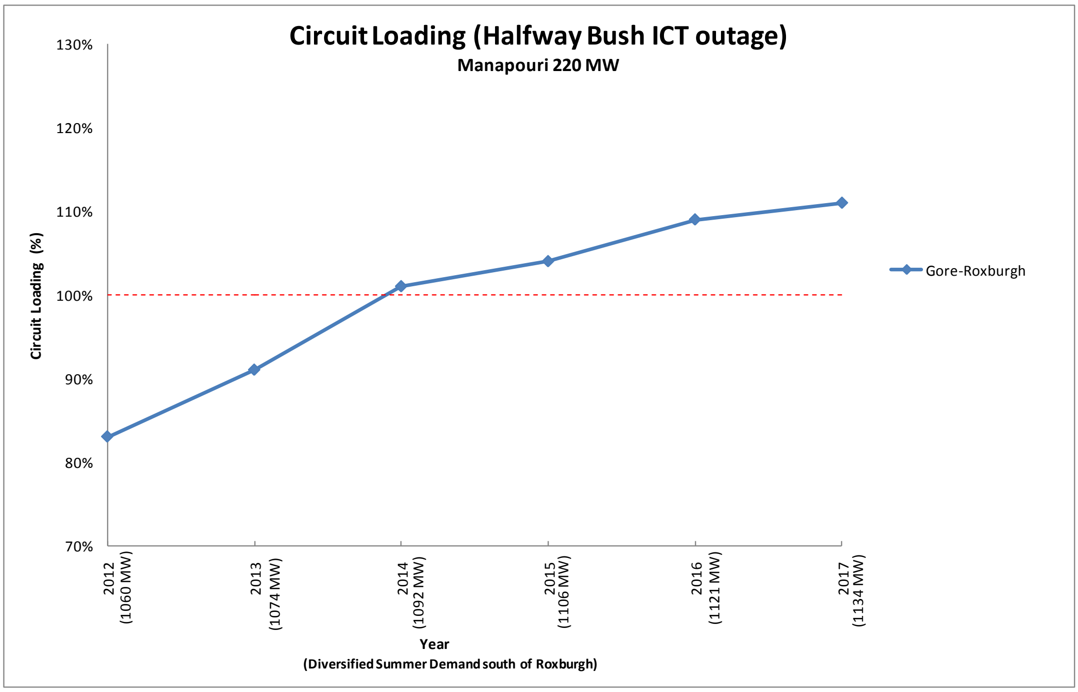


Figure 5-9: Grid constraints with the outage of Halfway Bush T4 transformer

Figure 5-10 shows the grid constraints with the outage of Roxburgh – Three Mile Hill circuit.

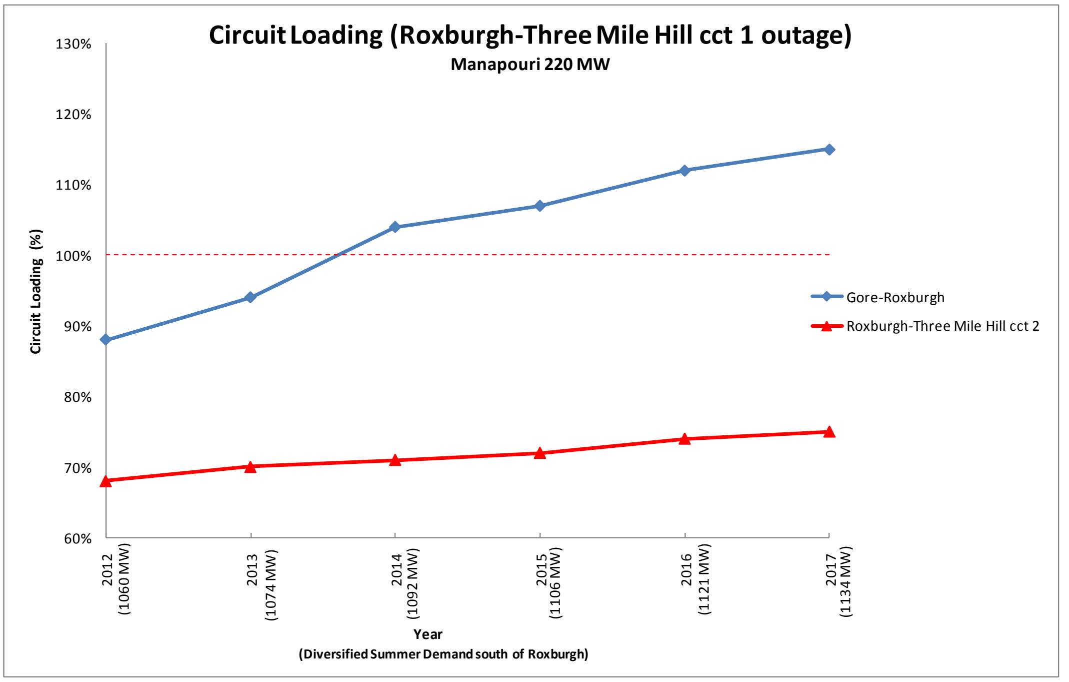


Figure 5-10: Grid constraints with the outage of Roxburgh – Three Mile Hill circuit

Table 5-2 shows a summary of the constraining circuits under different contingencies and the year when their capacities run out.

Table 5-2 Summary of constraining circuits under different contingencies

Contingency	Constraining Circuit	Voltage Level	Year when capacity run out based on Manapouri generation of 220 MW and peak demand
Invercargill – Roxburgh 1 or 2	Brydone – Gore	110 kV	2017
	Gore – Roxburgh	110 kV	<2012
	Invercargill – Roxburgh 2 or 1	220 kV	2016
Gore - Roxburgh	Balclutha- Berwick	110 kV	<2012
	Edendale – Invercargill	110 kV	2013
	Brydone – Gore	110 kV	2014
Balclutha – Berwick – Halfway Bush	Gore – Roxburgh	110 kV	<2012
	Edendale – Invercargill	110 kV	2014
	Brydone – Gore	110 kV	2017
Edendale - Invercargill	Gore – Roxburgh	110 kV	2013
	Balclutha – Berwick	110 kV	2014
Invercargill T1 transformer	Gore – Roxburgh	110 kV	2013
	Balclutha – Berwick	110 kV	2014
Roxburgh T10 transformer	Edendale – Invercargill	110 kV	2016
	Balclutha – Berwick	110 kV	2017
Balclutha - Gore	Gore – Roxburgh	110 kV	2014
Halfway Bush T4 transformer	Gore – Roxburgh	110 kV	2014
Roxburgh – Three Mile Hill	Gore – Roxburgh	110 kV	2014

Table 5-3 shows a summary of the low voltage constraints under different contingencies

Table 5-3 Summary of low voltage constraints under different contingencies

Contingency	Region with low voltage issue
Brydone - Edendale	Gore
Brydone - Gore	Gore
Edendale - Invercargill	Balclutha Edendale Gore Brydone
Gore - Roxburgh	Gore Brydone
Invercargill T1	Balclutha Edendale Gore Brydone Invercargill
Balclutha – Berwick – Halfway Bush	Balclutha Gore

5.3 Transmission Options

The short list of options (see Attachment D of the LSI Reliability GUP) considered a number of different upgrades to increase the transfer capacity to south of Roxburgh. The following upgrade options were short listed for detailed assessment:

- A new 220 kV circuit from Gore – Roxburgh
- A fourth interconnection point at Gore
- Series compensation on Three Mile Hill – North Makarewa circuit
- Re-configure Gore – Roxburgh circuit and Balclutha – Gore 110 kV circuits
- Special Protection Scheme to avoid overloading of assets
- Install reactive power support to address voltage stability issues.

Each upgrade option provides an increase in the transmission capacity; alleviate constraints on part of the network. The different development plans presented in section 5.4 are a combination of the above short list of options with appropriate constructability timing to ensure GRS is met for the planning period.

5.3.1 A new 220 kV circuit from Gore – Roxburgh

Table 5-4 shows the option of building a new 220 kV circuit between Gore and Roxburgh.

Table 5-4: New line option – new circuit parameters

Circuit	Voltage	From	To	Line length	Type	Rating MVA (summer/winter)
Gore - Roxburgh	220 kV	Roxburgh substation	Gore substation	84 km	Simplex Zebra at 75°C	347/382 MVA

5.3.2 A fourth interconnection point at Gore

A new interconnecting transformer is to be installed at Gore substation. The interconnecting transformer is to be tee connected onto Three Mile Hill – North Makarewa circuit. This configuration requires an approximately two kilometers of 220 kV circuit connected from Three Mile Hill – North Makarewa circuit into Gore substation.

Two interconnecting transformers are required to provide N-1 security.

Table 5-5: New interconnecting transformer option – new transformer rating

New asset	Voltage	Rating	Type
Gore interconnecting transformer	220/110 kV	100 MVA	10% impedance
Gore – Gore Tee (Tee off on Three Mile Hill – North Makarewa)	220 kV	210/256 MVA (summer/winter)	2 km of simplex Goat at 50°C

5.3.3 Series compensation on Three Mile Hill – North Makarewa circuit

This option installs a series capacitor on the Three Mile Hill – North Makarewa circuit to balance the power flow across the 220 kV circuits south of Roxburgh which utilizes the existing capacity of the transmission network.

Table 5-6 shows the two options of installing series capacitor on the Three Mile Hill – North Makarewa circuit.

Table 5-6: Series compensation option – series capacitor parameters

Connection	Install location	Impedance	Level of series compensation
Three Mile Hill – North Makarewa circuit	Three Mile Hill substation	40.6 ohms	50%
Three Mile Hill – North Makarewa circuit	Three Mile Hill substation	40.6 ohms upgrade to 56.8 ohms at a later stage	50% upgrade to 70% at a later stage

5.3.4 Special Protection Scheme to avoid overloading of assets

Special protection schemes are used to avoid overloading of assets as a temporary measure. It helps to provide sufficient build time for large upgrades. It is also used to meet N security for the non-core grid.

There are several types of SPS that could be implemented in Otago-Southland region to increase pre-contingency capacity during south transfer:

- Automatic post contingency load reduction. An example of this type of SPS is the automatic tripping of a reduction line at Tiwai Point to reduce in the loading on an Invercargill-Roxburgh 220 kV circuit following the tripping of one of the other circuit. This scheme has successfully been used in the past during periods of low Manapouri generation. It should be noted that the reduction line needs to be returned to service in a short time. This will require generation in the region be increased or load elsewhere in the region to be reduced.
- Automatic post contingency generation run up. An example of this type of SPS would be to automatically increase Manapouri generation to reduce loading on transmission circuits following a contingent event. There is a limited amount of generation in the region that could be used in such a SPS.

There are a number of SPS which could be used to manage asset loadings in the 110 kV network: These include:

- Load management. An example is an SPS which automatically manages load to maintain the loading on transmission assets within safe limits.
- Grid reconfiguration. An example is a scheme which splits the 110 kV network in response following the loss of an Invercargill – Roxburgh 220 kV circuit. The split could be effected by removing a transmission circuit from service (e.g. the Brydone-Gore 110 kV circuit), sectionalizing a bus (e.g. Gore 110 kV bus and 33 kV load) or by removing interconnecting transformers from service.

The System Operator needs to incorporate the functionality of SPS's within its operational tools. In some cases, this may require upgrades to the tools where the functionality of the SPS is complicated.

Table 5-7 shows the SPS options.

Table 5-7: SPS options

SPS	Monitor assets	Pre/Post contingency actions
Manapouri generation run-up	Loading on Invercargill – Roxburgh 1 and 2	Manapouri generation run up to 275 MW post contingency
Opening of Brydone – Gore circuit	Loading on Gore – Roxburgh circuit	Open Brydone – Gore circuit post contingency
Gore bus sectionalise	Loading on Gore – Roxburgh circuit	Split Gore bus into three sections pre contingency when circuit loading exceeds a limit or automatically post contingency
Open Gore Interconnecting transformer	Loading on Gore – Roxburgh circuit	Open Gore Interconnecting transformer

5.3.5 Re-configure Gore – Roxburgh circuit and Balclutha – Gore 110 kV circuits

The Gore bus is to be split so the Gore – Roxburgh and Balclutha – Gore 110 kV circuits are disconnected normally from Gore 110 kV bus to form a single circuit between Balclutha and Roxburgh. This option only requires re-configuration of the existing assets connected to the Gore bus.

Figure 5-11 shows the re-configuration.

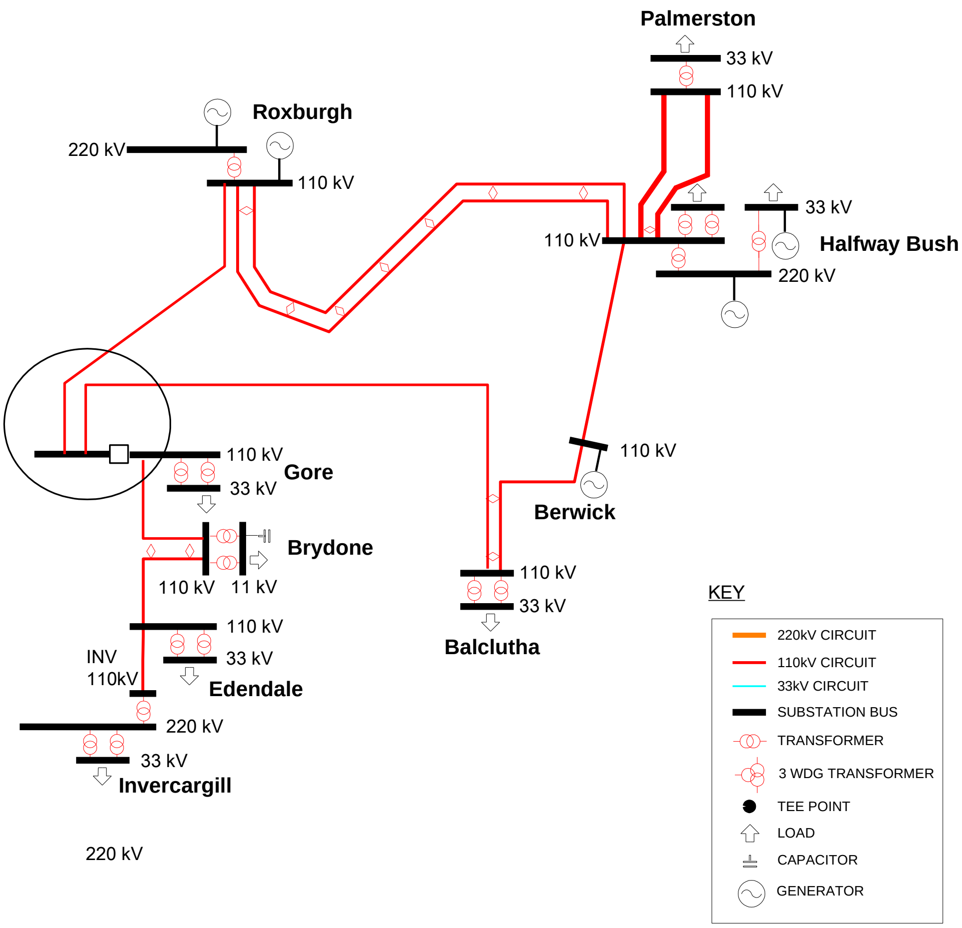


Figure 5-11: Re-configuration of Gore- Roxburgh and Balclutha – Gore circuits

5.4 Investment Proposal options

The various upgrade options are combined to form the development plans for the Investment Proposal. The development plans propose upgrade options to address:

- core grid constraints to meet N-1 security and
- non-core grid constraints to meet N security; or N-1 security where economically justified.

The development plan is done by progressively identifying circuit constraints and then upgrade options are included to removes these constraints. The staging of the development options may include SPS to provide sufficient build time or to delay a large upgrade investment.

5.4.1 Proposal Option 0

Under this option it is proposed to manage:

- the 220 kV contingencies by:
  - (i) installation of Special Protection Schemes (SPS) from 2012 to 2017 and
  - (ii) installation of a series capacitor (70% series compensation) on Three Mile Hill – North Makarewa to utilize the existing capacity of the 220 kV circuit for the remaining planning period; and
- the 110 kV contingencies by:
  - (i) load curtailment at 110 kV GXPs from 2012 to 2028 and
  - (ii) installation of two 220/110 kV transformers at Gore for the remaining planning period.

Figure 5-12 illustrates the overall network arrangement after implementing the upgrades proposed under this option. Table 5-8 is a summary of the stage upgrade options with an indicative timing.

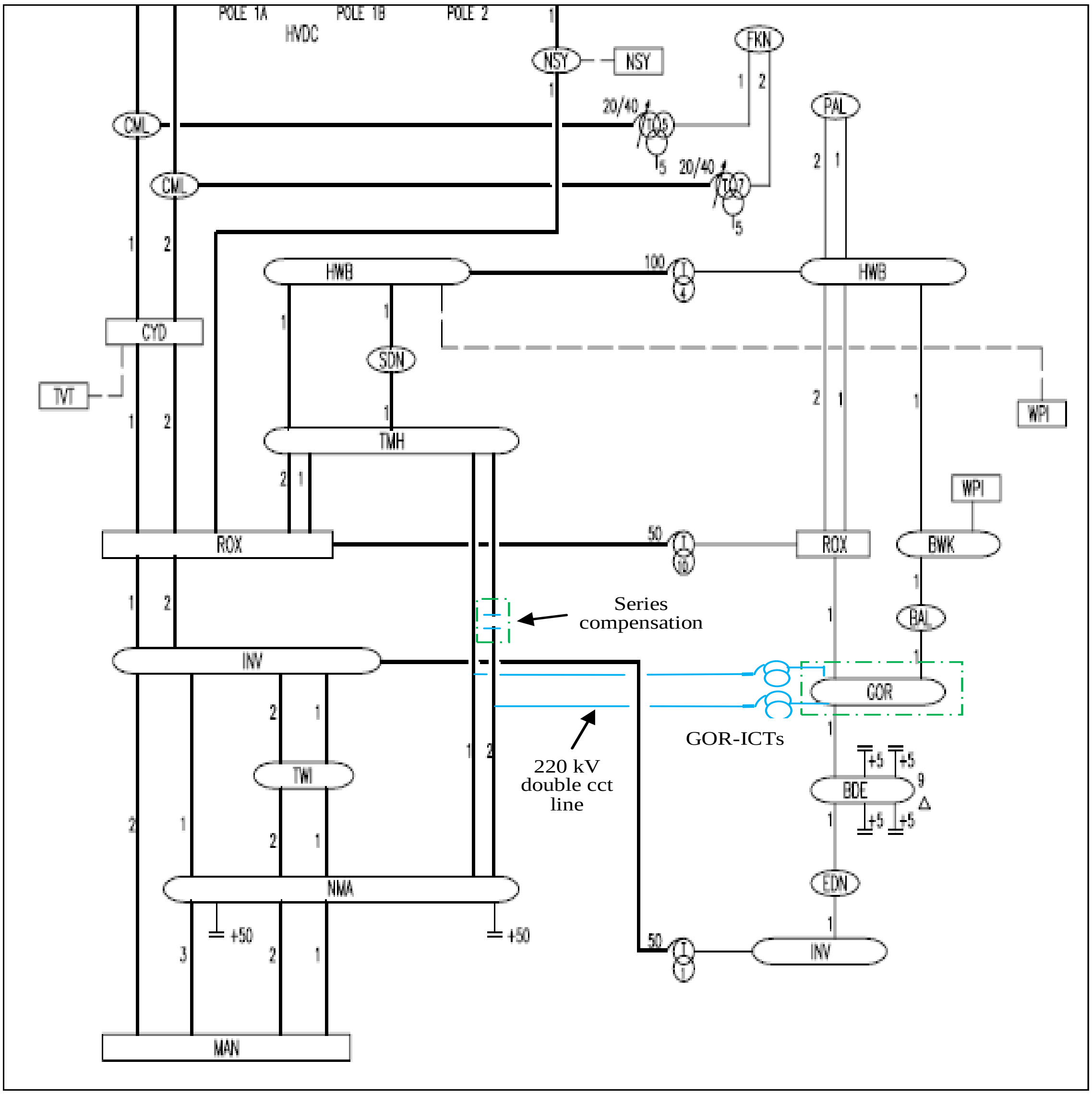


Figure 5-12: Proposal Option 0 overall network arrangement after implementing the upgrades

Table 5-8: Proposal Option 0 (base case) staged development plan

Year	Upgrade	Details
2011	Halfway Bush T4 backfeed protection (SPS)	
2012	SPS: • Open 110 kV Brydone - Gore circuit post contingency for 220 kV Invercargill - Roxburgh contingency when required • Gore load shedding for 110 kV contingencies	
	Install shunt capacitors at Gore 33 kV	20 Mvar (5 x 4 Mvar)
2013	Replace Roxburgh T10 220/110 kV transformer	1 x 220/110 kV, 150 MVA, 15%
	Replace Invercargill T1 220/110 kV transformer	1 x 220/110 kV, 100 MVA, 10%
2015	Sectionalize the Gore 110 kV bus into three sections with 110 kV Brydone-Gore 110 kV circuit open. Gore load off-take only from the first two sections: • Section 1: Gore - Roxburgh circuit with approximately three quarters of the load • Section 2: Balclutha - Gore circuit with approximately a quarter of the load • Section 3: Brydone - Gore circuit open	
	Install shunt capacitor at Gore 110 kV (Section 1)	20 Mvar
2016	SPS to trip a reduction line at Tiwai Point followed by re-dispatch of generation	Up to 265 MW
2018	Series Capacitor on a North Makarewa – Three Mile Hill circuit at Three Mile Hill end (70%)	58.6 ohms
2025	Install shunt capacitor at Gore 110 kV (Section 2)	10 Mvar
2028	Install 2 x 220/110 kV transformers at Gore	2 x 220/110 kV, 100 MVA, 10%
	2 km of 220 kV double circuit line tee connection from North Makarewa – Three Mile Hill line to Gore substation	Simplex Goat at 50°C

The series capacitor could be installed to its full value of 70% initially, or a staged development of 50% initially increasing to 70% when required. For Option 0, both are very close economically. The full value of 70% was selected for this development option.

5.4.2 Proposal Option 4

Under this option it is proposed to manage:

- the 220 kV contingencies by:

(i) installation of Special Protection Schemes (SPS) from 2012 to 2016 and

(ii) installation of a new 220 kV line between ROX and GOR for the remaining planning period; and

- the 110 kV contingencies by:

(i) load curtailment at 110 kV GXPs from 2012 to 2014 and

(ii) installation of two ICTs at GOR for the remaining planning period.

Figure 5-13 illustrates the overall network arrangement after implementing the upgrades proposed under this option. Table 5-9 is a summary of the stage upgrade options with an indicative timing.

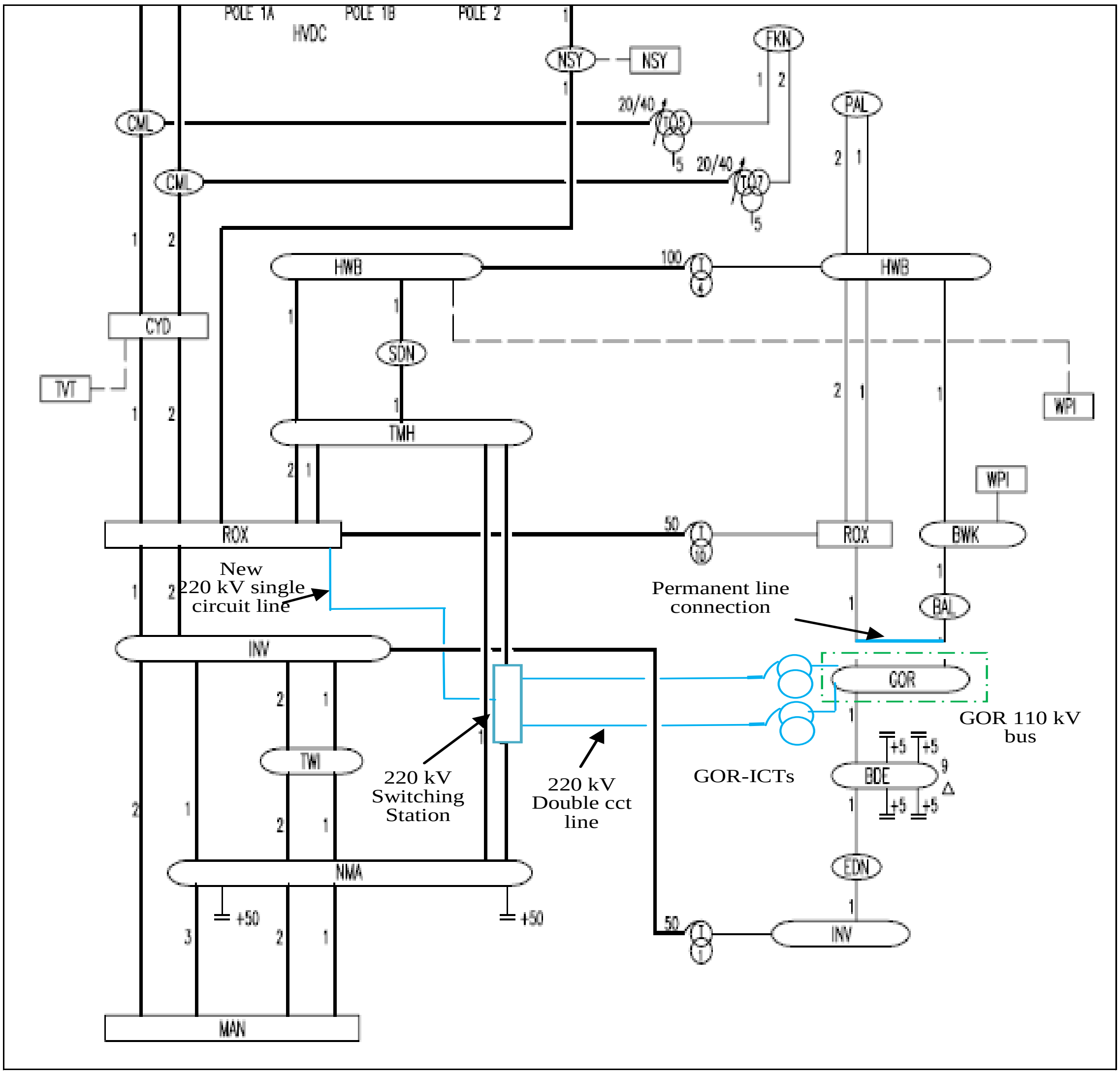


Figure 5-13: Proposal Option 4 overall network arrangement after implementing the upgrades

Table 5-9: Proposal Option 4 staged development plan

Year	Upgrade	Details
2011	Halfway Bush T4 backfeed protection (SPS)	
2012	Install shunt capacitor at Balclutha 33 kV	
	SPS: Open 110 kV Brydone – Gore circuit post contingency for 220 kV Invercargill – Roxburgh contingency when required Gore load shedding for 110 kV contingencies	
2013	Replace Roxburgh T10 220/110 kV transformer	1 x 220/110 kV, 150 MVA, 15%
	Replace Invercargill T1 220/110 kV transformer	1 x 220/110 kV, 100 MVA, 10%
2014	Install 2 x 220/110 kV transformers at Gore	2 x 220/110 kV, 100 MVA, 10%
	2 km of 220 kV double circuit line tee connection from North Makarewa – Three Mile Hill line to Gore substation	Simplex Goat at 50°C
	220 kV switching station adjacent to North Makarewa – Three Mile Hill line near Gore	
	Install shunt capacitor at Gore 33 kV	20 Mvar (5 x 4 Mvar)
	Upgrade SPS (open Brydone – Gore circuit post contingency) to include opening of Gore 220/110 kV transformer	
	SPS to trip a reduction line at Tiwai Point followed by re-dispatch of generation	Up to 265 MW
2017	New 220 kV single circuit line from Roxburgh to Gore (220 kV switching station adjacent to the North Makarewa – Three Mile Hill line near Gore)	Approximately 86 km long, Simplex Zebra at 75^{0}C
	Split the Gore bus so the 110 kV Gore – Roxburgh and Balclutha – Gore circuits are normally disconnected from the Gore 110 kV bus to normally form a single circuit between Roxburgh and Balclutha	

5.4.3 GUP Option 8

Under this option it is proposed to manage:

- the 220 kV contingencies by:

(i) installation of Special Protection Schemes (SPS) from 2012 to 2017 and

(ii) installation of a series capacitor (70% series compensation) on Three Mile Hill – North Makarewa to utilize the existing capacity of the 220 kV circuit for the remaining planning period; and

- the 110 kV contingencies by:

(i) load curtailment at 110 kV GXPs from 2012 to 2014 and

(ii) installation of one 220/110 kV transformer at Gore initially then a second 220/110 kV transformer at a later stage for the remaining planning period.

Figure 5-14 illustrates the overall network arrangement after implementing the upgrades proposed under this option. Table 5-10 is a summary of the stage upgrade options with an indicative timing.

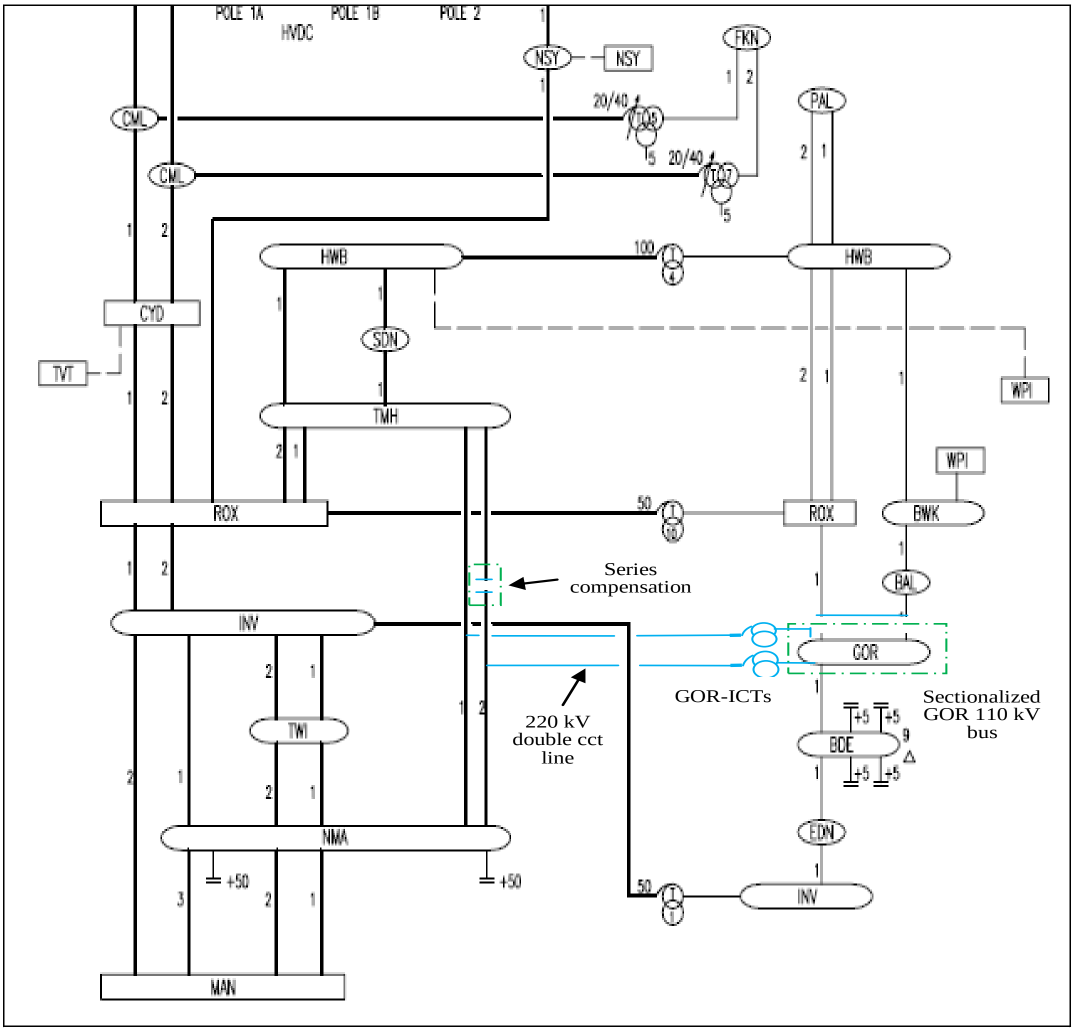


Figure 5-14: GUP Option 8 overall network arrangement after implementing the upgrades

Table 5-10: GUP Option 8 staged development plan

Year	Upgrade	Details
2011	Halfway Bush T4 backfeed protection (SPS)	
2012	Sectionalize the Gore 110 kV bus into three sections with 110 kV Brydone – Gore circuit open. Gore load off-take only from the first two sections: Section 1: Gore – Roxburgh circuit with approximately three quarters of the load Section 2: Balclutha – Gore circuit with approximately a quarter of the load Section 3: Brydone – Gore circuit open	
	Install shunt capacitor at Gore 33 kV (Section 2)	20 Mvar (5 x 4 Mvar)
2013	Replace Roxburgh T10 220/110 kV transformer	1 x 220/110 kV, 150 MVA, 15%
	Replace Invercargill T1 220/110 kV transformer	1 x 220/110 kV, 100 MVA, 10%
2014	Install 1st Gore 220/110 kV transformer	1 x 220/110 kV, 100 MVA, 10%
	2 km of 220 kV double circuit line tee connection from North Makarewa – Three Mile hill line to Gore substation (only one circuit used initially)	Simplex Goat at 50C
	Upgrade SPS (sectionalize the Gore 110 kV bus into three sections) to include opening of Gore 220/110 kV transformer	
	Install shunt capacitor at Gore 110 kV (Section 1)	20 Mvar
	SPS to trip a reduction line at Tiwai Point followed by re-dispatch of generation	Up to 265 MW
2017	Install shunt capacitor at Gore 33 kV (Section 1)	10 Mvar
2018	Series Capacitor on a North Makarewa – Three Mile Hill circuit at Three Mile Hill end (70%)	58.6 ohms
2024	Install shunt capacitor at Gore 110 kV (Section 1)	10 Mvar
	Install shunt capacitor at Gore 110 kV (Section 2)	10 Mvar
2028	Split the Gore bus so the 110 kV Gore – Roxburgh and Balclutha – Gore circuits are normally disconnected from the Gore 110 kV bus to normally form a single circuit between Roxburgh and Balclutha	
2028	SPS to trip a reduction line at Tiwai Point followed by re-dispatch of generation	
	Install 2nd Gore 220/110 kV transformer	1 x 220/110 kV, 100 MVA, 10%
2032	Upgrade existing North Makarewa 220 kV shunt capacitors from 50 Mvar to 70 Mvar	2 x 20 Mvar increase

The series capacitor could be installed to its full value of 70% initially, or a staged development of 50% initially increasing to 70% when required. For Option 8, both are very close economically. The full value of 70% was selected for this development option.

5.4.4 GUP Option 9

Under this option it is proposed to manage:

- the 220 kV contingencies by:

(i) installation of Special Protection Schemes (SPS) from 2012 to 2014 and

(ii) installation of a series capacitor (50% series compensation initially upgradable to 70% series compensation at a later stage) for the remaining planning period; and

- the 110 kV contingencies by:

(i) load curtailment at 110 kV GXPs from 2012 to 2014 and

(ii) installation of two 220/110 kV transformers at Gore for the remaining planning period.

Figure 5-15 illustrates the overall network arrangement after implementing the upgrades proposed under this option. Table 5-11 is a summary of the stage upgrade options with an indicative timing.

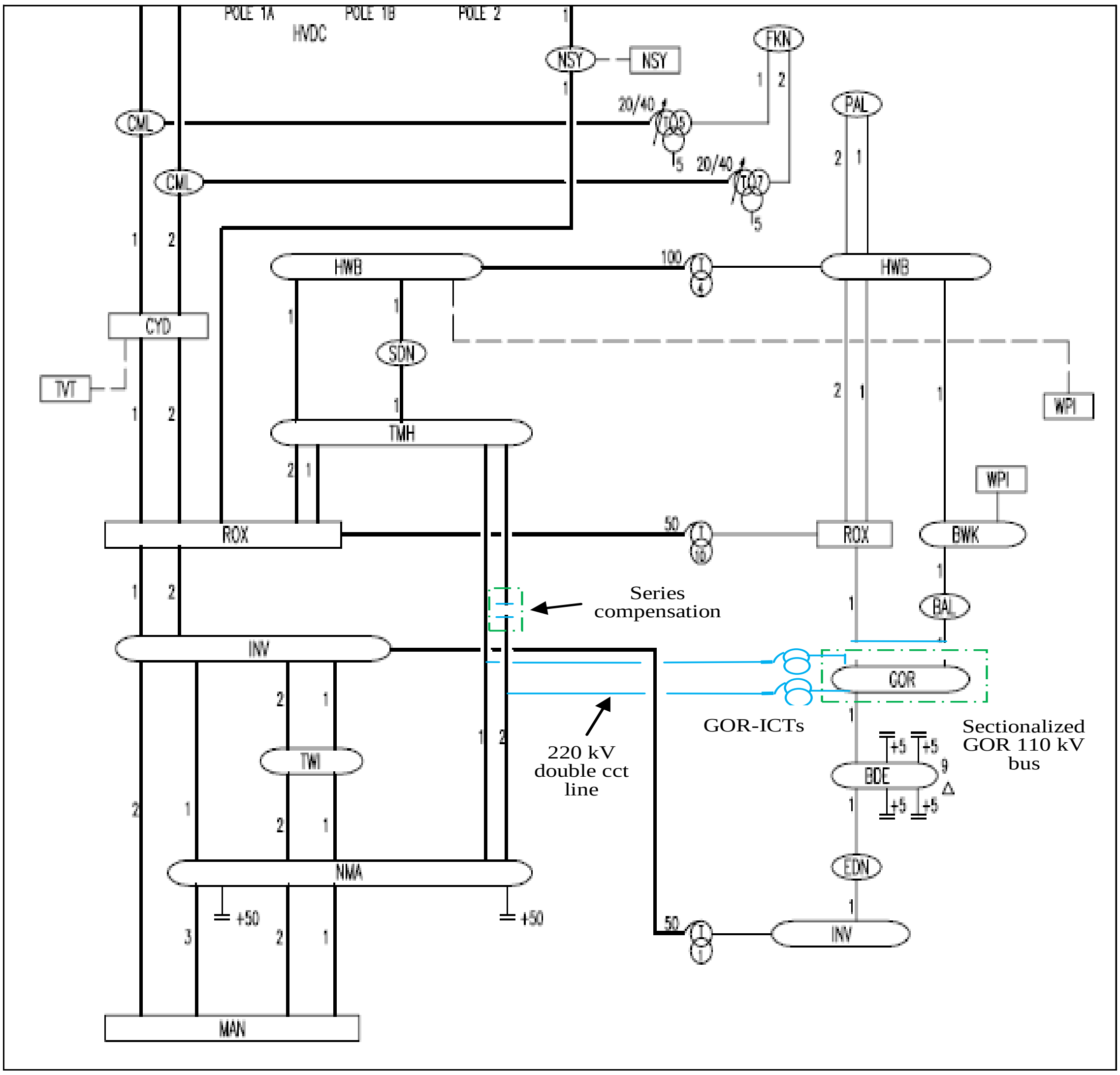


Figure 5-15: GUP Option 9 overall network arrangement after implementing the upgrades

Table 5-11: GUP Option 9 staged development plan

Year	Upgrade	Details
2011	Halfway Bush T4 backfeed protection (SPS)	
2012	SPS: Open Brydone – Gore circuit post contingency for 220 kV Invercargill – Roxburgh contingency when required Gore load shedding for 110 kV contingencies	
	Install shunt capacitor at Balclutha 33 kV	2 x 4 Mvar
2013	Replace Roxburgh T10 220/110 kV transformer	1 x 220/110 kV, 150 MVA, 15%
	Replace Invercargill T1 220/110 kV transformer	1 x 220/110 kV, 100 MVA, 10%
2014	Install 2 x 220/110 kV transformers at Gore	2 x 220/110 kV, 100 MVA, 10%
	2 km of 220 kV double circuit line tee connection from NMA-TMH line to Gore substation	Simplex Goat at 50°C
	Split the Gore bus so the 110 kV Gore – Roxburgh and Balclutha – Gore circuits are normally disconnected from the Gore 110 kV bus to normally form a single circuit between Roxburgh and Balclutha	
	SPS to trip a reduction line at Tiwai Point followed by re-dispatch of generation	Up to 265 MW
2015	Series Capacitor on a North Makarewa – Three Mile Hill circuit at Three Mile Hill end (50%)	40.8 ohms
2020	SPS – Open Gore 220/110 kV transformer	
2022	Upgrade series compensation from 50% to 70%	From 40.8 ohms to 56.8 ohms
	Upgrade the existing North Makarewa 220 kV shunt capacitors from 50 Mvar to 70 Mvar	2 x 20 Mvar increase

For Option 9, the series capacitor is a staged development of 50% initially increasing to 70% when required. Alternatively, it could be installed at 70% initially. A staged development of the series capacitor is selected because it is more economic, and it is technically prudent to initially have a lower level of compensation as we grow to understand this technology.

5.5 GUP option discussion

5.5.1 GUP Option 0

Strategy

The reference case (Option 0) effectively maximises the use of the existing 110 kV circuits through a three-way split of the 110 kV bus at Gore when necessary to manage the loading on the 110 kV circuits and 220/110 kV interconnecting transformers. The split is implemented so that:

- approximately three quarters of the Gore load is supplied from Roxburgh by the Gore-Roxburgh 110 kV circuit
- approximately a quarter of the Gore load is supplied from Halfway Bush by the Halfway Bus-Berwick-Balclutha-Gore 110 kV circuit
- the Edendale and Brydone loads are supplied from Invercargill by the Invercargill – Edendale – Brydone – Gore 110 kV circuit.

Southflow capacity issue

The Gore bus split addresses the southflow capacity issue by:

- removing the parallel connection of the constraining 110 kV Gore – Roxburgh circuit and Roxburgh 220/110 kV transformer from the two Invercargill – Roxburgh 220 kV circuits, allowing the full capacity of the Invercargill – Roxburgh 220 kV circuits to be used.

- continuing to use the Gore – Roxburgh and Halfway Bush – Gore 110 kV circuits to supply part of the LSI load (Gore).

The above strategy maximises the use of the 110 kV network for south flow capacity. However, following the tripping of a 220 kV Invercargill – Roxburgh circuit it is also necessary to have Manapouri generation run-up until a series capacitor is installed.

110 kV security

When the Gore 110 kV bus and load is split, a large amount of shunt capacitor support is needed to support the voltage at the end of the long Gore – Roxburgh and Halfway Bush – Gore circuits. Switching the capacitors in and out of service will require careful management in the real time operating environment, to ensure the pre- and post-contingency voltages are within the acceptable range, the voltage step when switching is within an acceptable range, and the circuit loading is minimised. This requires the size of each capacitor to be relatively small. In particular, the first capacitors to be installed are 5 x 4 Mvar capacitors connected to the 33 kV bus, which provides the ability to fine tune the amount of reactive support in real time once the larger 20 Mvar and 10 Mvar capacitors are connected to the 110 kV bus at a later date.

With the Gore 110 kV bus split all the 110 kV connected GXP's are on n security. There will be a loss of supply should a circuit or transformer trip. However, the Gore 110 kV bus needs to be split only when there is a high load off-take or high levels of south flow, and then only for some contingencies. Therefore, by keeping the Gore 110 kV bus solid as often as possible provides n-1 security for as long as possible, minimising the risk of a loss of supply. This requires Special Protection Schemes to automatically split the Gore 110 kV bus post contingency to prevent circuit and transformer overloading. Replacing the Roxburgh and Invercargill transformers reduces the time when the load is on n security, and the transformers are replaced as soon as reasonably practical to gain the maximum security benefit.

The existing Roxburgh 220/110 kV transformer is only 50 MVA and has an off-load tap changer. It requires a minimum level of generation connected to the Roxburgh 110 kV bus to be constrained on to prevent overloading. The 110 kV Gore – Roxburgh circuit also constrains transmission, and to prevent this circuit from overloading when the Gore bus is solid requires the maximum level of generation connected to the Roxburgh 110 kV bus to be constrained down. These are conflicting requirements for the generation connected to the Roxburgh 110 kV bus.

Roxburgh and Invercargill 220/110 kV transformer replacement

The Roxburgh 220/110 kV transformer is programmed for replacement within the next five years based on Condition Assessment. Replacing it with a 150 MVA transformer with an on-load tap changer:

- removes the transformer overloading issue
- allows zero generation on the Roxburgh 110 kV bus (when Manapouri generation is low), to reduce the loading on the 110 kV Gore – Roxburgh circuit
- allows the Roxburgh 110 kV voltage to be optimised to reduce the loading on the 110 kV Gore – Roxburgh circuit and removes the need for an additional capacitor at Gore to control the Gore bus voltage.

The Invercargill 220/110 kV transformer is also programmed for replacement within the next five years based on Condition Assessment. Replacing it with a 100 MVA transformer with an on-load tap changer results in a small reduction in loading of the 110 kV circuits, reducing the time when Gore 110 kV bus needs to be split, placing the load on n security.

5.5.2 GUP Option 4

Strategy

The strategy for Option 4 is to use Option 9 as a starting point, but replace the series capacitor with a new line. There is a new 220 kV switching station at or near Gore. There has a two-way split of the Gore 110 kV bus:

- Balclutha – Gore and Gore – Roxburgh, to form a Balclutha – Gore connection
- two Gore 220/110 kV transformers, the Gore supply transformers, and the Brydone – Gore circuit

Southflow capacity issue

With respect to the southflow capacity issue:

- the split removes the constraint caused by the Gore – Roxburgh circuit by disconnecting the circuit at Gore and reconnecting it to form a Balclutha – Roxburgh circuit
- increases the loading of the 220 kV circuits, as the Gore – Roxburgh circuit no longer supplies part of the LSI load (Gore)

Following the tripping of a 220 kV Invercargill – Roxburgh circuit it is necessary to have Manapouri generation run-up until the new 220 kV Gore – Roxburgh line is built.

110 kV security issue

With respect to the security of the 110 kV, it is the same as for Option 9 (the Proposal), namely:

- the split forms a Balclutha – Roxburgh circuit, which maintains security to Balclutha. Shunt capacitors are required at Balclutha to maintain the voltage when Balclutha is supplied from Roxburgh only
- the two Gore 220/110 kV transformers provide security to the Gore load
- security to Edendale and Brydone is provided by the 220/110 kV transformer at Invercargill and the 220/110 kV reinforcement at Gore
- no shunt capacitors are required at Gore for voltage support

The practical build date for the Gore 220/110 kV transformers is 2014. The practical build date for the new 220 kV Gore – Roxburgh line is 2017, after which full n-1 security is achieved. Up to then it is not possible to deliver n-1 security for the peak load under the prudent forecast, especially during periods of low hydro inflows. Therefore, there will be periods when the Gore load is on n security. The strategy prior to 2014 to minimise the duration when load is on n security by investing only in those assets which are required after 2014. Between 2014 and 2017 the strategy is to install capacitors at Gore to minimise the duration when the load is on n security. At times of high load up to 2017, Special Protection Scheme(s) are used to trip the Brydone – Gore circuit and/or shed load at Gore if this is necessary to prevent circuits or 220/110 kV transformers from overloading.

New build prior to 2014 which minimises the time when Gore is on n security is:

- replacement Roxburgh 220/110 kV transformer
- replacement Invercargill 220/110 kV transformer
- Gore 110 kV bus and load splitting
- shunt capacitors at Balclutha

Up to 2014, the base case (Option 0) and Option 4 are identical.

New build between 2014 and 2017 which minimises the time when Gore is on n security is:

- shunt capacitors at Gore

5.5.3 GUP option 8

Strategy

The strategy for Option 8 is to use the base case (Option 0) as the starting point, but to provide n-1 security for the 110 kV network with a single 220/110 kV transformer at Gore teed off one of the North Makarewa – Three Mile Hill circuits.

Southflow capacity issue

With respect to the southflow capacity issue before and after the Gore 220/110 kV transformer is installed:

- the loading on the 220 kV Invercargill – Roxburgh circuits remains almost unchanged
- the loading on the 220 kV Roxburgh – Three Mile Hill circuits remains almost unchanged
- the loading on the 110 kV Gore – Roxburgh circuit remains almost unchanged
- the loading on the Invercargill 220/110 kV transformer decreases

Therefore, compared with the base case, the single 220/110 kV transformer at Gore does not significantly affect the southflow capacity. Following the tripping of a 220 kV Invercargill – Roxburgh circuit it is still necessary to split the Gore 110 kV bus (with shunt capacitors to support the voltage), and have Manapouri generation run-up until a series capacitor is installed. The timing of some investments are delayed one or two years.

110 kV security issue

With respect to the security of the 110 kV, following the outage of any of the existing 110 kV circuits the load continues to be supplied through the Gore 220/110 kV transformer. The most severe contingency is the outage of the Gore 220/110 kV transformer or the 220 kV North Makarewa – Three Mile Hill circuit the transformer is connected to. The system configuration is then identical to the base case (Option 0). At high loads it requires the Gore 110 kV bus and load to be split to prevent circuit overloading. When bus splitting is no longer sufficient to prevent circuit overloading, a second Gore 220/110 kV transformer is required.

The practical build date for the Gore 220/110 kV transformer is 2014, after which there is n-1 security. Up to then it is not possible to deliver n-1 security for the peak load under the prudent forecast, especially during periods of low hydro inflows. Therefore, there will be periods when the Gore load is on n security. The strategy prior to 2014 to minimise the duration when load is on n security by investing only in those assets which will also be required after 2014. At times of high load, Special Protection Scheme(s) are used to trip the Brydone – Gore circuit and/or shed load at Gore if this is necessary to prevent circuits or 220/110 kV transformers from overloading.

New build prior to 2014 which minimises the time when Gore is on n security is:

- replacement Roxburgh 220/110 kV transformer
- replacement Invercargill 220/110 kV transformer
- shunt capacitors at Balclutha
- Gore 110 kV bus and load splitting

Up to 2014, the base case (Option 0) and Option 8 are identical.

5.5.4 GUP option 9

Strategy

The strategy for the proposal (Option 9) is to use Option 8 as the starting point, but install two 220/110 kV transformers at Gore to avoid the need for much of the investment in the shunt capacitors for voltage support. This has a two-way split of the Gore 110 kV bus:

- Balclutha – Gore and Gore – Roxburgh, to form a Balclutha – Gore connection
- two Gore 220/110 kV transformers, the Gore supply transformers, and the Brydone – Gore circuit

Southflow capacity issue

With respect to the southflow capacity issue:

- the split removes the constraint caused by the Gore – Roxburgh circuit by disconnecting the circuit at Gore and reconnecting it to form a Balclutha – Roxburgh circuit
- increases the loading of the 220 kV circuits, as the Gore – Roxburgh circuit no longer supplies part of the LSI load (Gore)

Following the tripping of a 220 kV Invercargill – Roxburgh circuit it is necessary to have Manapouri generation run-up until a series capacitor is installed.

110 kV security issue

With respect to the security of the 110 kV:

- the split forms a Balclutha – Roxburgh circuit, which maintains security to Balclutha. Shunt capacitors are required at Balclutha to maintain the voltage when Balclutha is supplied from Roxburgh only
- the two Gore 220/110 kV transformers provide security to the Gore load
- security to Edendale and Brydone is provided by the 220/110 kV transformer at Invercargill and the 220/110 kV reinforcement at Gore
- no shunt capacitors are required at Gore for voltage support

The practical build date for the Gore 220/110 kV transformers is 2014, after which there is n-1 security. Up to then it is not possible to deliver n-1 security for the peak load under the prudent forecast, especially during periods of low hydro inflows. Therefore, there will be periods when the Gore load is on n security. The strategy prior to 2014 to minimise the duration when load is on n security by investing only in those assets which will also be required after 2014. At times of high load up to 2014, Special Protection Scheme(s) are used to trip the Brydone – Gore circuit and/or shed load at Gore if this is necessary to prevent circuits or 220/110 kV transformers from overloading.

New build prior to 2014 which minimises the time when Gore is on n security is:

- replacement Roxburgh 220/110 kV transformer
- replacement Invercargill 220/110 kV transformer
- shunt capacitors at Balclutha

Compared with the base case (Option 0) up to 2014, the base case has the shunt capacitors at Gore while Option 9 has the series capacitors at Balclutha.

5.6 Other issues

5.6.1 Roxburgh and Invercargill 220/110 kV transformers

The existing Roxburgh and Invercargill interconnecting transformers each comprise of three single-phase units with an on-site spare. They are programmed for replacement within the next five years as part of an overall programme to manage Transpower's aging fleet of single phase transformers.

Following the failure of an in-service transformer unit, the on-site spare could be put into service in approximately 24 hours. The replacement Roxburgh and Invercargill interconnecting transformers will be three-phase units, with no on-site spare. Following the failure of an in-service transformer, it will take approximately four weeks to replace it with a strategic system spare transformer. This would have a negative impact on the ability to supply the load and security for Option 0 (base case providing n security).

The Proposal (Option 9) has two interconnecting transformers at Gore. The Gore interconnecting transformers provide a backup in the event of a failure of the replacement Roxburgh or Invercargill transformers, removing any supply constraint and limiting the amount of load on n security during the approximate four weeks to replace the faulted transformer.

5.6.2 Halfway Bush T4 Backfeed Protection (SPS)

The Halfway Bush T4 backfeed protection is common to all developments options and is required to ease maximum load limits from all 110 kV connected GXPs during outages of a 220 kV circuit between Three Mile Hill, Halfway Bush and South Dunedin.

With a circuit out of service for maintenance, it is required to operate the power system so that the System Operator's Principle Performance Objectives (PPOs) are met. That is, with one circuit out of service and should a second circuit trip, the loading on the remaining in-service equipment must be their capacity and all voltages be within required limits.

Consider the case of the 220 kV circuits between Three Mile Hill, Halfway Bush and South Dunedin, with one circuit out of service for maintenance and one circuit trips. Halfway Bush and/or South Dunedin are then disconnected from the 220 kV bus at Three Mile Hill, and all load supplied from the 220 kV must flow through the Halfway Bush 220/110 kV (T4) transformer, from the 110 kV network to the 220 kV. This will cause very low bus voltages and severe overloading of the 110 kV circuits.

To prevent this, the Halfway Bush T4 transformer is also taken out of service during a 220 kV circuit outage. Should a second 220 kV circuit trip, then there is a total loss of supply to the load supplied from the 220 kV bus at Halfway Bush and South Dunedin. This meets the requirements of the PPOs for the 220 kV system since no equipment is overloaded and there are no voltage violations.

However, taking Halfway Bush T4 transformer out of service removes from service the largest of the three 220/110 kV transformers supplying the 110 kV network (the other two 220/110 kV transformers are at Roxburgh and Invercargill). The load off-take from all the grid exit points supplied from the 110 kV (between Edendale and Palmerston) must be within the capacity of the 110 kV network should any 110 kV circuit trip so that the PPOs are still met. Even if the output from 110 kV connected generation from Roxburgh and Waipori is maximised, severe load restrictions are still required.

The 110 kV load restrictions can be eased by keeping Halfway Bush T4 in service during a 220 kV circuit outage. Should a 110 kV circuit trip, then the 110 kV network continues to be supported through the Halfway Bush T4 transformer. Therefore, the 110 kV network can supply a higher level of load off-take from the 110 kV network between Edendale and Palmerston. The backfeed protection does not affect the security of the load supplied from the 220 kV bus at Halfway Bush and South Dunedin. Should a second 220 kV circuit trip, then Halfway Bush T4 is automatically tripped by new backfeed protection, causing a loss of supply to the load supplied from the 220 kV bus at Halfway Bush and South Dunedin. This meets the requirements of the PPOs.

Appendix A Demand Forecasts

Appendix A contains the demand forecast (summer and winter) used in the power system analysis.

A.1 Demand Forecast – Summer (MW)

Code	Point of Supply	Summer Power Factor	Summer Diversity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
GXP	Otago/ Southland																											
BAL	Balclutha	0.9649	88.3%	27.8	28.5	28.6	28.8	28.9	29.1	29.2	29.4	29.5	29.7	29.8	30.0	30.1	30.3	30.4	30.6	30.7	30.9	31.0	31.2	31.3	31.5	31.6	31.8	32.0
BDE	Brydone	0.7696	66.6%	9.0	9.8	9.9	10.1	10.2	10.4	10.6	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
CYD	Clyde	0.8956	78.6%	6.9	10.4	10.5	10.6	10.7	10.8	11.0	11.1	11.2	11.3	11.4	11.5	11.7	11.8	11.9	12.1	12.2	12.3	12.5	12.6	12.7	12.9	13.1	13.3	13.5
CML	Cromwell	0.9977	86.4%	19.5	24.7	25.6	26.6	27.7	28.8	29.9	31.1	32.4	33.7	35.0	35.6	36.0	36.5	37.0	37.5	38.0	38.6	39.1	39.6	40.2	40.8	41.4	42.0	42.6
EDN	Edendale	0.9778	58.0%	22.9	27.8	29.0	30.3	31.6	33.0	34.5	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
FKN	Frankton	0.9916	92.7%	37.2	41.9	43.8	45.7	47.7	49.8	52.0	54.2	56.6	59.1	61.7	62.7	63.6	64.6	65.5	66.5	67.5	68.5	69.5	70.5	71.5	72.6	73.7	74.8	75.9
GOR	Gore	0.9645	96.0%	29.5	36.9	36.9	36.9	42.8	49.2	62.0	65.0	68.1	70.1	72.1	74.2	76.3	77.1	77.8	78.5	79.3	80.1	80.9	81.6	82.4	83.2	84.1	84.9	85.8
HWB - A	Halfway Bush-A	0.9749	72.1%	54.7	62.0	63.1	64.2	65.4	66.6	66.8	67.1	67.4	67.8	68.1	68.4	68.7	69.0	69.3	69.6	69.9	70.2	70.5	70.9	71.2	71.5	71.9	72.3	72.6
HWB - B	Halfway Bush-B	0.9749	72.1%	54.7	62.0	63.1	64.2	65.4	66.6	66.8	67.1	67.4	67.8	68.1	68.4	68.7	69.0	69.3	69.6	69.9	70.2	70.5	70.9	71.2	71.5	71.9	72.3	72.6
INV	Invercargill	0.9821	98.3%	90.7	95.5	97.0	98.4	99.4	100.4	101.4	102.2	103.0	103.7	104.5	105.0	105.6	106.1	106.6	107.2	107.7	108.2	108.8	109.3	109.9	110.4	111.0	111.5	112.1
NSY	Naseby	0.9942	85.6%	24.8	27.5	28.0	28.5	29.0	29.5	29.7	30.0	30.3	30.5	30.8	31.1	31.3	31.6	31.9	32.2	32.5	32.7	33.0	33.3	33.6	34.0	34.3	34.6	35.0
NMA	North makarewa	0.9571	96.5%	51.6	58.0	60.1	62.4	64.7	67.1	69.6	72.2	75.0	77.8	80.7	81.5	82.3	83.0	83.8	84.6	85.4	86.2	87.0	87.9	88.7	89.6	90.5	91.4	92.3
PAL	Palmerston	0.9837	83.9%	7.0	7.4	7.5	7.6	7.6	7.7	7.8	7.9	8.0	8.0	8.1	8.2	8.3	8.4	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.1	9.2	9.3
SDN	Soputh Dunedni	0.9863	98.9%	62.9	67.0	68.0	69.0	70.0	71.1	71.8	72.5	73.3	74.0	74.7	75.1	75.5	75.9	76.3	76.6	77.0	77.4	77.8	78.2	78.6	79.0	79.4	79.8	80.2
TWI	Tiwai	0.9704	99.7%	609.4	514.7	619.4	640.0	640.0	640.0	640.0	645.0	650.0	655.0	660.0	665.0	670.0	675.0	680.0	685.0	690.0	690.0	690.0	690.0	690.0	690.0	690.0	690.0	690.0
Summer Before Diversity				1,108.5	1,074.2	1,190.6	1,223.3	1,241.2	1,260.0	1,283.2	1,303.6	1,320.8	1,337.1	1,353.8	1,365.3	1,376.8	1,386.9	1,397.0	1,407.2	1,417.5	1,422.8	1,428.2	1,433.6	1,439.0	1,444.9	1,450.7	1,456.7	1,462.6
RegionPeak				1,043.8	1,000.3	1,114.8	1,145.7	1,161.6	1,178.3	1,199.6	1,217.7	1,234.0	1,249.5	1,265.3	1,276.3	1,287.2	1,296.8	1,306.5	1,316.2	1,325.9	1,330.8	1,335.6	1,340.5	1,345.5	1,350.7	1,356.0	1,361.4	1,366.8
South of Roxburgh				965.8	908.4	1,019.9	1,047.6	1,060.3	1,073.5	1,091.6	1,106.2	1,118.9	1,130.6	1,142.5	1,151.8	1,161.1	1,169.1	1,177.1	1,185.1	1,193.2	1,196.3	1,199.4	1,202.5	1,205.7	1,209.0	1,212.3	1,215.6	1,219.0

A.2 Demand Forecast – Winter (MW)

Code	Point of Supply	Winter Power Factor	Winter Diversity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
GXP	Otago/ Southland																											
BAL	Balclutha	0.9614	90.6%	26.3	27.5	27.6	27.7	27.9	28.0	28.2	28.3	28.4	28.6	28.7	28.9	29.0	29.2	29.3	29.5	29.6	29.8	29.9	30.1	30.2	30.4	30.5	30.7	30.8
BDE	Brydone	0.7885	79.9%	9.2	9.8	9.9	10.1	10.2	10.4	10.6	10.7	10.9	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
CYD	Clyde	0.5409	39.1%	8.1	10.4	10.5	10.6	10.7	10.8	11.0	11.1	11.2	11.3	11.4	11.5	11.7	11.8	11.9	12.1	12.2	12.3	12.5	12.6	12.7	12.9	13.1	13.3	13.5
CML	Cromwell	0.9949	95.3%	24.8	31.8	33.4	35.0	36.8	38.6	40.5	42.6	44.8	47.0	49.4	50.4	51.4	52.3	53.3	54.3	55.3	56.4	57.4	58.5	59.6	60.8	62.0	63.3	64.5
EDN	Edendale	0.9785	55.4%	22.8	27.6	28.3	29.3	30.1	30.9	31.7	34.0	36.4	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
FKN	Frankton	0.9875	95.6%	46.9	52.8	55.4	58.1	60.9	63.9	67.0	70.3	73.8	77.4	81.2	82.6	83.8	85.0	86.3	87.6	88.8	90.2	91.5	92.9	94.2	95.6	97.1	98.5	100.0
GOR	Gore	0.9731	86.7%	29.8	34.2	34.2	34.2	39.2	46.6	59.9	62.4	64.8	66.4	68.0	69.6	71.3	72.0	72.7	73.4	74.1	74.8	75.6	76.3	77.0	77.8	78.6	79.4	80.2
HWB - A	Halfway Bush-A	0.9831	90.8%	59.8	67.9	69.4	71.0	72.6	74.2	74.6	74.9	75.3	75.6	75.9	76.3	76.6	77.0	77.3	77.7	78.0	78.4	78.8	79.1	79.5	79.9	80.3	80.7	81.1
HWB - B	Halfway Bush-B	0.9831	90.8%	59.8	67.9	69.4	71.0	72.6	74.2	74.6	74.9	75.3	75.6	75.9	76.3	76.6	77.0	77.3	77.7	78.0	78.4	78.8	79.1	79.5	79.9	80.3	80.7	81.1
INV	Invercargill	0.9809	98.6%	90.0	95.9	97.3	98.7	99.8	100.8	101.8	102.7	103.6	104.5	105.4	106.2	107.0	107.8	108.6	109.4	110.2	111.0	111.9	112.7	113.6	114.4	115.3	116.1	117.0
NSY	Naseby	0.9940	76.8%	24.8	27.5	28.0	28.5	29.0	29.5	29.7	30.0	30.3	30.5	30.8	31.1	31.3	31.6	31.9	32.2	32.5	32.7	33.0	33.3	33.6	34.0	34.3	34.6	35.0
NMA	North makarewa	0.9646	86.5%	50.3	56.9	58.2	59.6	60.9	62.4	63.8	65.3	66.8	68.4	70.0	70.7	71.3	72.0	72.7	73.3	74.0	74.7	75.4	76.2	76.9	77.6	78.4	79.2	80.0
PAL	Palmerston	0.9761	91.0%	7.5	8.0	8.0	8.1	8.2	8.3	8.4	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0
SDN	Soputh Dunedni	0.9809	96.5%	70.5	75.4	76.9	78.5	80.1	81.7	82.9	84.1	85.4	86.7	88.0	88.9	89.8	90.7	91.6	92.5	93.4	94.4	95.3	96.2	97.2	98.2	99.2	100.2	101.2
TWI	Tiwai	0.9738	97.2%	578.6	619.4	619.4	640.0	640.0	640.0	640.0	645.0	650.0	655.0	660.0	665.0	670.0	675.0	680.0	685.0	690.0	690.0	690.0	690.0	690.0	690.0	690.0	690.0	690.0
Summer Before Diversity				1,109.2	1,213.0	1,226.1	1,260.4	1,278.9	1,300.2	1,324.6	1,344.8	1,365.4	1,384.1	1,402.1	1,414.7	1,427.2	1,438.8	1,450.5	1,462.2	1,474.0	1,480.9	1,487.9	1,495.0	1,502.1	1,509.7	1,517.3	1,525.0	1,532.8
RegionPeak				1,038.6	1,133.0	1,144.8	1,177.2	1,193.7	1,212.6	1,234.1	1,252.1	1,270.4	1,287.5	1,304.3	1,316.2	1,327.8	1,338.8	1,349.7	1,360.8	1,371.9	1,378.2	1,384.6	1,391.1	1,397.6	1,404.5	1,411.5	1,418.5	1,425.6
South of Roxburgh				947.9	1,027.0	1,034.5	1,062.3	1,074.0	1,087.9	1,104.3	1,117.0	1,129.6	1,140.8	1,151.5	1,160.8	1,170.2	1,178.7	1,187.3	1,195.9	1,204.5	1,208.3	1,212.2	1,216.0	1,219.9	1,224.0	1,228.1	1,232.2	1,236.4

