TRANSPOWER

# N-1 Thermal and Voltage Study

System Security Forecast 2024

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## IMPORTANT

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**Contact Details**

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|---|---|
| Address: | Transpower New Zealand Ltd<br>Waikoukou<br>22 Boulcott Street<br>PO Box 1021<br>Wellington<br>New Zealand |
| Telephone: | +64 4 495 7000 |
| Email: | system.operator@transpower.co.nz |
| Website: | www.transpower.co.nz |

# Contents

# 1 Executive summary

As part of the System Security Forecast (SSF), the System Operator has conducted comprehensive N-1 Thermal and Voltage studies to assess the robustness of the New Zealand power system over the next three years. These studies consider both current and future asset capabilities, particularly committed generation and grid asset projects. Identifying potential risks and identifying mitigating measures are critical to maintain grid security.

We assessed power flows across fourteen Grid Zones and the 220 kV backbones of the major islands to ensure safe asset dispatch without causing overloads or voltage limit violations following a contingency. We also conducted voltage stability studies to verify that stability could be maintained.

**Key findings**

The SSF's N-1 contingency studies have identified critical contingencies that require attention to prevent thermal, Code voltage limits, and voltage stability issues. For these contingencies, the report notes both future grid projects that will resolve the issues, and operational measures that the System Operator can apply to mitigate the issues and enhance the security of the power system.

North Island 220 kV backbone

Critical contingencies for a high north flow involve circuits from Stratford to Huntly, and Tokaanu to Whakamaru. These are resolved by future grid projects related to Net-Zero Grid Pathways, increasing the thermal capacity of the affected 220 kV circuits. Until these projects are completed, we have in place operational measures such as Special-Protection-Schemes (SPS) and security constraints.

Contingencies affecting the 220 kV backbone and the HVDC south transfer involve circuits between Bunnythorpe, Tokaanu, and Whakamaru. The severity of a potential thermal overload depends on the power injected by the Stratford and lower North Island wind farms, as well as the local load in Wellington. We will continue to manage this challenge operationally by constraining the HVDC south flow.

South Island 220 kV backbone

The major contingencies remain the 220 kV circuits between Aviemore and Benmore. For high HVDC north transfer, we mitigate the risk through an existing SPS on these circuits. For high HVDC south transfer, the mitigation is to increase the generation in the lower South Island by applying existing constraints.

Grid Zones

The N-1 contingency studies revealed scenarios where a single N-1 contingency could lead to significant overloading or voltage issues in certain Grid Zones. However, some of these will be resolved by committed grid projects within the next three years. The most significant assets which would experience overloading or voltage issues in these scenarios are:

- Hamilton 220/110 kV interconnecting transformers: a contingency of one interconnector may overload the remaining interconnector under dry (low hydro) conditions. This can be managed by increasing Karapiro and Arapuni generation during peak through security constraints, provided sufficient water is available. Otherwise, the dry hydro scenario will require load management in Grid zone 03.

- Hamilton Region 110 kV network: a contingency of either circuit between Hamilton, Piako and Waihou will require load management within PowerCo's network during winter peak demand. A contingency of either circuit between Hamilton and Karapiro will overload the remaining circuit, but we can mitigate this overload by increasing Karapiro generation through security constraints.

- Kaitimako 220/110 kV interconnecting transformers: a contingency of one interconnector may overload the remaining interconnector under dry conditions. We can manage this by increasing Kaimai generation during peak, provided sufficient water is available. Otherwise, the dry hydro scenario will require load management in Tauranga, Te Matai, Kaitimako and Mt Maunganui, or an SPS put in place as a post-operational measure.

- Redclyffe 220/110 kV interconnecting transformers: a contingency of one interconnector may overload the remaining interconnector. This is currently managed by an SPS, but an additional Redclyffe interconnector will resolve the issue in February 2025.

- Bunnythorpe and Whanganui 110 kV circuits: a contingency of the circuit between Hāwera and Stratford may overload the circuits between Bunnythorpe and Whanganui, leading to undervoltage. Mitigation involves enabling the existing Hāwera Automatic Undervoltage Load Shedding Scheme during low local generation.

- Timaru 110 kV bus: a contingency of either circuit between Ashburton, Timaru and Twizel may cause undervoltage at Timaru. The existing operational options are to adjust the voltage setpoints of local generation and adjust tap positions of the Timaru interconnectors both pre- and post-contingency.

Voltage stability

Voltage stability remains a challenge in the upper North Island due to contingencies involving Huntly Unit 5 or 220 kV circuits towards Auckland. To meet the stability requirements with the forecast load, we will require all reactive compensation devices, including new and upcoming STATCOMs. We will monitor this in the real-time and should voltage stability become a concern, we will increase local generation and manage load as an operational mitigation.

We do not foresee any issues with managing the upper South Island load under intact network conditions.

We expect the new Frankton supply transformers to sufficiently increase the voltage stability limit for contingencies involving 220 kV circuits between Clyde-Cromwell-Twizel.

Impact of new committed generation

Nearly 85% of new committed generation are inverter-based resources, giving about 970 MW of additional capacity. The N-1 contingency studies show that new connections have not caused any significant thermal violations or voltage stability issues. We will be closely assessing new connections as they are confirmed and will provide updates if required.

<u>Overvoltage management over troughs</u>

In the previous SSF, assessments indicated several transmission circuits would need to be removed from service to mitigate any over voltages in Northland and Auckland region during low load periods. With the commissioning of new reactors and STATCOMs, the need to switch off transmission circuits during light load has decreased.

# 2 Introduction

## 2.1 Purpose

This N-1 Thermal and Voltage Study analyses core grid security risks under N-1 conditions. These risks can lead to thermal or equipment component violations, voltage Code limit violations and if not properly managed, cascade failure.

## 2.2 Scope of studies

The report covers the 3-year study period from Summer 2024 to Winter 2027 and includes committed connection or disconnection of assets advised to the System Operator. Some studies extend up to 2028 to cover the impact of committed projects beyond the 3-year period.

Power flow studies and voltage stability analysis have been carried out to study the thermal, static voltage, and voltage stability limits for both North and South Island backbones and the Grid Zones. Different system conditions have been used for backbones and Grid Zones depending on the local constraints and scope of the study, which will be detailed in later chapters. Table 2-1 sets out the scope studied in this report by region.

Appendix A: Grid Configuration details the available assets in the study period, including the committed grid upgrades and generation/storage projects. This report also covers the load forecast and load duration curves used in this report.

Appendix B: Study Methodology details the methodology used in identifying the security risks under N-1 conditions.

Table 2-1: Scope of study in each region

| Grid | N-1 Thermal, Component and Static Voltage Limits | Voltage Stability Risks | Security Issues from Connection or Disconnection of Assets | Overvoltage Risks over the Trough Periods |
|---|---|---|---|---|
| **NIBB** | ✓ | ✓ | ✓ | ✓ |
| **SIBB** | ✓ | ✓ | ✓ | ✓ |
| **NI-GZ1** | ✓ | ✓ | ✓ | ✓ |
| **NI-GZ2** | ✓ | | ✓ | ✓ |
| **NI-GZ3** | ✓ | | ✓ | |
| **NI-GZ4** | ✓ | | ✓ | |
| **NI-GZ5** | ✓ | | ✓ | |
| **NI-GZ6** | ✓ | | | |
| **NI-GZ7** | ✓ | | | |
| **NI-GZ8** | ✓ | ✓ | | |
| **SI-GZ9** | ✓ | ✓ | | ✓ |
| **SI-GZ10** | ✓ | | | |
| **SI-GZ11** | ✓ | | ✓ | |
| **SI-GZ12** | ✓ | ✓ | | ✓ |
| **SI-GZ13** | ✓ | ✓ | | |
| **SI-GZ14** | ✓ | ✓ | ✓ | ✓ |

# 3 North Island grid backbone

## 3.1 Grid backbone overview

The New Zealand power system consists of two separate networks, one in the North Island and one in the South Island, which are connected via an HVDC link. The backbone of the power system is a 220 kV network that spans the length of both islands. The bi-directional HVDC link is connected at Haywards in the North Island and Benmore in the South Island.

During daylight periods and normal rainfall patterns in the South Island, power tends to flow from the South Island to the North Island. Conversely, during non-peak periods, such as late evenings and early mornings, and in years of low rainfall in South Island, power can flow from the North Island to the South Island.

Several contingencies can lead to constraints on the North Island 220 kV grid backbone under intact network conditions. Different constraints are applied depending on whether the HVDC has a north transfer or a south transfer. This chapter describes contingencies affecting the North Island 220 kV grid backbone and provides an overview of system limitations on inter-regional transfer in the North Island.

The North Island 220 kV backbone consists of:

- Four circuits from Wellington to Bunnythorpe
- Three circuits from Bunnythorpe to Wairakei and Whakamaru
- Three circuits connecting Wairakei and Whakamaru
- Two circuits from Bunnythorpe to Brunswick, and three circuits from Brunswick to Stratford
- Two circuits from Stratford to Huntly
- Eight circuits from Huntly, Ohinewai and Whakamaru to Auckland

The North Island 220 kV grid backbone is shown geographically in Figure 3-1 and as a single line diagram in Figure 3-2. The highlighted elements in the single line diagram represent committed projects and upgrades.


Figure 3-1: Geographic representation of North Island 220 kV grid backbone

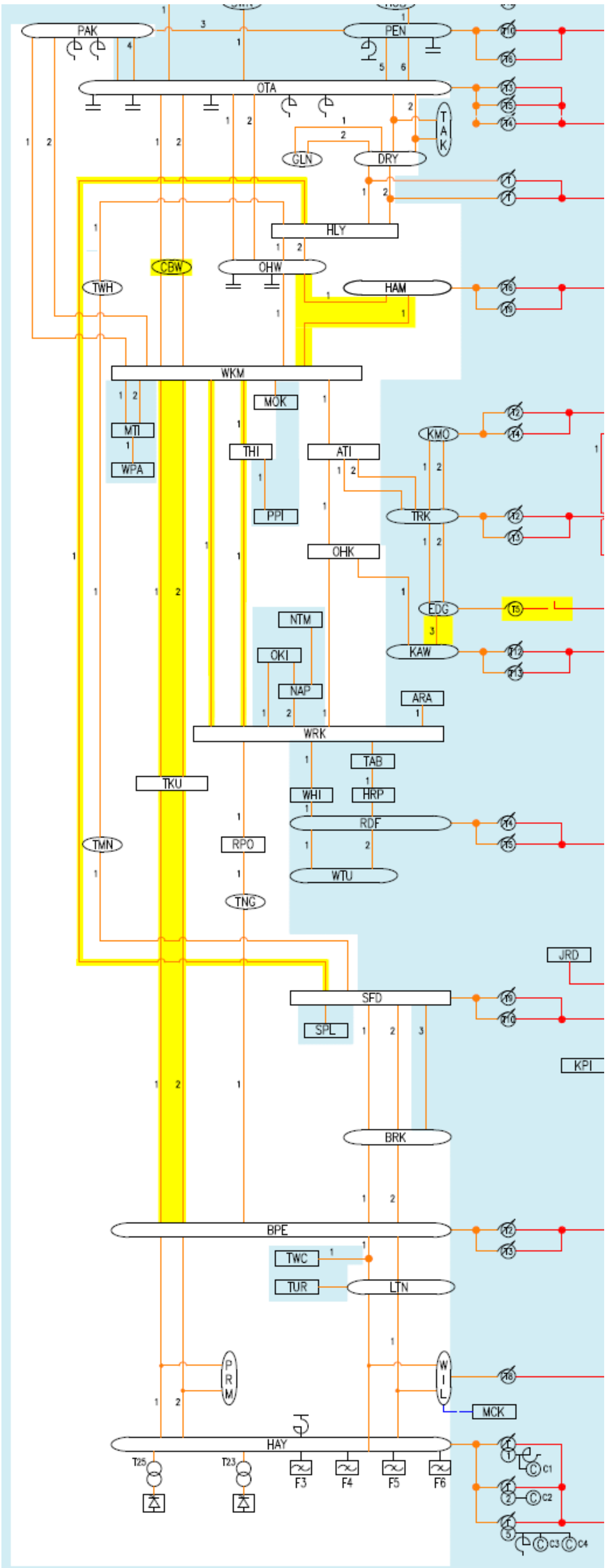

Figure 3-2: Single line diagram of North Island 220 kV grid backbone

### 3.1.1 Committed projects and upgrades

The committed projects and upgrades that impact the North Island grid backbone over the period of study are shown in Table 3-1 and Table 3-2 respectively.

Table 3-1: North Island summary of committed grid upgrades

| Asset | Changes | Commissioning Date | Grid Zone |
|---|---|---|---|
| Wairau Road second Transformer (T9) | Install WRD T9 220/110 kV, 250 MVA transformer | September-2026 | 1 |
| Bombay GXP | Bombay-Hamilton-1 110 kV circuit disconnected. | Commissioned | 2 |
| Ōtāhuhu STATCOM | Install a 150 Mvar STATCOM at Ōtāhuhu 220 kV. | Commissioned | 2 |
| Glenbrook STATCOM (NZ Steel) | Installation of a 74 MVAr STATCOM on Glenbrook 33kV dirty bus to support voltage variations caused by the new arc furnace load. | December-2025 | 2 |
| Hamilton–Whakamaru and Ohinewai–Whakamaru 220 kV circuits | Implement variable line ratings on the Hamilton–Whakamaru and Ohinewai–Whakamaru circuits. | March-2027 | 3 |
| Hautapu GXP | New 220 kV GXP commissioned at Cambridge West, supplied from Ōtāhuhu–Whakamaru–1 and 2 circuits. | Commissioned | 3 |
| Huntly–Stratford 220 kV circuit | NZGP Stage 1 - Remove line protection static limit on the Huntly–Stratford circuit. | April-2026 | 3, 6 |
| Kawerau 220/110 kV Interconnecting Transformer Replacement | Replace Kawerau–T13 with a 250 MVA transformer. | Commissioned | 4 |
| Lichfield–Tarukenga–1 110 kV Circuit | Reconductor 2 km section on the Lichfield–Tarukenga–1 circuit. | Commissioned | 4 |
| Tokaanu–Whakamaru 220 kV circuits | NZGP Stage 1 - thermal upgrade of the Tokaanu–Whakamaru 220 kV circuits with variable line ratings. | 2026 | 4 |
| Te Mihi–Wairakei, Te Mihi–Whakamaru and Wairakei– Whakamaru 220 kV circuits | NZGP Stage 1 - Thermally upgrade the Wairakei–Whakamaru C line. (Te Mihi–Wairakei, Te Mihi–Whakamaru and Wairakei–Whakamaru circuits) | 2026 | 4 |
| Edgecumbe–Kawerau 3 220 kV circuit | NZGP Stage 1 - Thermally upgrade the Edgecumbe–Kawerau 3 220 kV circuit. | August-2026 | 4 |
| Tokaanu–Whakamaru 220 kV circuits | NZGP Stage 1 - Duplex the Tokaanu–Whakamaru 1 and 2 220 kV circuits. | June-2026, June-2027 | 4 |
| Te Matai Transformer Replacement | Te Matai T1 capacity increased from 30 to 80MVA | December-2025 | 4 |
| Wairakei Supply Transformer | Wairakei T29 and T30 capacity increased from 50MVA to 60MVA | December-2025 | 4 |
| Edgecumbe T5 Transformer Replacement | Replace EDG-T5 with old KAW-T13 | December-2026 | 4 |
| Edgecumbe-Kawerau 110kV split | Split the 110 kV: New N/O Kawerau CB172 & CB112 to Edgcumbe and close Edgecumbe CB292 to Edgecumbe T5. | Commissioned | 4 |
| Redclyffe Interconnecting Transformer | Install third Redclyffe Interconnecting Transformer (RDF T5). | Commissioned | 5 |

| Asset | Changes | Commissioning Date | Grid Zone |
|---|---|---|---|
| Brunswick Supply Transformer | Brunswick new supply transformer | December-2027 | 6 |
| Hawera Supply Transformers | Outdoor to indoor conversion project and protection upgrade project | Commissioned | 6 |
| Bunnythorpe–Ongarue 110 kV system | NZGP Stage 1 - Ongarue 110 kV split. | April-2026 | 7 |
| Bunnythorpe–Tokaanu circuits | NZGP Stage 1 - Thermally upgrade the Bunnythorpe–Tokaanu circuits and implement variable line ratings. | April-2029 | 7 |
| Marton Supply Transformers | Outdoor to indoor conversion project and protection upgrade project (removes the protection constraint) | July-2026 | 7 |

Table 3-2: North Island summary of committed generation/storage

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date | Grid Zone |
|---|---|---|---|---|---|---|
| Ruakaka BESS (Meridian) | Northland | Battery | +/-100 MW, 200 MWh | Bream Bay | Commissioned | 1 |
| Pukenui (Aquila Clean Energy) | Northland | Solar | 17.1MW | Kaikohe (embedded) | Commissioned | 1 |
| Twins Rivers (Ranui Generation Limited) | Northland | Solar | 24MW | Kaitaia/ Kaikohe (embedded) | 2026 | 1 |
| Ruawai (Northpower Limited) | Northland | Solar | 14MW | Maungaturoto (embedded) | Commissioned | 1 |
| Te Papa Reireia (Maungaturoto Solar Farm Project LP) | Northland | Solar | 17.6MW | Maungaturoto (embedded) | Nov 2025 | 1 |
| Kaiwaikawe Wind Farm (Mercury) | Northland | Wind | 70MW | Maungatapere (Embedded) | 2026 | 1 |
| Waerenga Solar Farm (Island Green Power Ltd) | Auckland | Solar | 190 | Awariki Road (new) | 2027 | 2 |
| Glenbrook BESS (Contact Energy) | Auckland | Battery | +/-100 MW, 200 MWh | Glenbrook | 2026 | 2 |
| Karapiro (Mercury) | Hamilton | Hydro | 112 MW | Karapiro | Commissioned | 3 |
| Whitianga Solar farm (Lodestone) | Hamilton | Solar | 23.75 MW | Kopu | 2026 | 3 |
| Rangiriri Solar Farm (Island Green Power Ltd) | Hamilton | Solar | 146.7 | Glen Murray Road (new) | 2027 | 3 |
| Tauhei Solar Farm (Harmony Energy) | Hamilton | Solar | 150MW | Waihou | 2026 | 3 |
| Taiohi Solar Farm (NewPower Energy) | Hamilton | Solar | 22.4 MW | Huntly (embedded) | Commissioned | 3 |
| Huntly BESS (Genesis) | Hamilton | Battery | +/-100 MW, 200 MWh | Huntly | 2026 | 3 |
| Te Herenga o Te Ra Solar Farm | Edgecumbe | Solar | 35 | Waiotahe | Commissioned | 4 |

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date | Grid Zone |
|---|---|---|---|---|---|---|
| (Lodestone Energy Limited) | | | | | | |
| Te Huka Geothermal (Contact Energy) | Edgecumbe | Geothermal | 51 | Tauhara | Commissioned | 4 |
| Edgecumbe Solar (Helios Energy Limited) | Edgecumbe | Solar | 28.7 | Edgecumbe | 2026 | 4 |
| TOPP2 (Eastland Generation) | Edgecumbe | Geothermal | 55 | Kawerau | Dec 2025 | 4 |
| Te Ahi O Maui (Eastland Generation) | Edgecumbe | Geothermal | 27.4 | Kawerau | Commissioned | 4 |
| Ngatamariki (Mercury) | Edgecumbe | Geothermal | 54 | Nga Awa Purua | Dec 2025 | 4 |
| Edgecumbe Solar Farm – EDS (Aquila Clean Energy) | Edgecumbe | Solar | 27 | Edgecumbe (embedded) | 2026 | 4 |
| Te Mihi G5 & G6 (Contact Energy) | Edgecumbe | Geothermal | 102 | Te Mihi | 2027 | 4 |
| Tuai (Genesis) | Hawkes Bay | Hydro | 68 | Tuai | Commissioned | 5 |

## 3.2 North Island system conditions

Thermal constraints of the grid depend on the dispatch of the generators. Thus, different generation scenarios can lead to various network constraints in both backbone and 110 kV network. Six possible generation scenarios (system conditions) have been identified to examine the system's capabilities and potential constraints in the system. In the grid backbone studies, network analyses have been conducted under these six system conditions. The system conditions are listed and discussed below.

### 3.2.1 North Island system condition 1: low upper North Island thermal generation during winter

North Island system condition 1 (NS1) represents the scenario where thermal generation in the Waikato and Upper North Island (WUNI) area is low during winter peak. The upper North Island region is defined as the area encompassing Grid Zones 1 and 2, the Auckland and Northland regions and includes Huntly power station. In this scenario, only Huntly Unit 5 and Unit 6 have been dispatched while the remaining Huntly Rankine units are unavailable. NS1 is designed to focus on thermal and voltage stability issues where power is transported from remote areas in the lower North Island to Whakamaru and Huntly.

### 3.2.2 North Island system condition 2: low upper North Island thermal generation during summer

North Island system condition 2 (NS2) represents the scenario where thermal generation in the WUNI area is low during the high summer peak. In this scenario, only Huntly Unit 5 has been dispatched, while the remaining Huntly Rankine units are unavailable. NS2 is designed to focus on thermal and voltage stability issues where power is transported from remote areas in the lower North Island to Whakamaru and Huntly, considering summer circuit ratings.

### 3.2.3 North Island system condition 3: HVDC south transfer during winter

North Island system condition 3 (NS3) represents a scenario of low hydro generation in the South Island, requiring a high HVDC south transfer close to the winter peak. It depicts a South Island dry year scenario with very low wind generation in winter. NS3 is designed to focus on thermal issues where power is transported from Huntly and central North Island (CNI) to Haywards.

While it remains possible to transfer power south via the HVDC link during winter, it is unlikely that the North Island will have sufficient generation capacity to deliver a high HVDC south transfer during winter peak load when there is low or no wind generation. Therefore, this study reflects the winter overnight or afternoon period (85% of the winter peak load), as HVDC south transfer cannot be achieved during peak loads.

This system condition also addresses voltage stability issues in Grid Zone 8.

### 3.2.4 North Island system condition 4: HVDC south transfer during summer

North Island system condition 4 (NS4) represents a scenario where low hydro generation in the South Island requiring high HVDC south transfer during the summer peak. The generation scenario is similar to NS3, but with summer circuit ratings. It depicts a South Island dry year scenario with very low wind generation in summer. The NS4 is designed to focus is on thermal issues where power is transported from Huntly and the central North Island (CNI) to Haywards, considering summer circuit ratings.

The study reflects the summer overnight or afternoon period (85% of the of summer peak load) as HVDC south transfer cannot be achieved during the peak loads.

### 3.2.5 North Island system condition 5: light load during summer

North Island system condition 5 (NS5) represents the summer night, light load period where high voltage issues on the grid are a concern in the Te Kowhai, Auckland and Wellington areas. The NS5 is designed to focus on the high voltage issues in the North Island grid backbone.

### 3.2.6 North Island system condition 6: North Island dry condition during winter

North Island system condition 6 (NS6) represents a scenario of low hydro generation in the North Island during the winter peak, depicting a 'dry' period in the North Island. NS6 is designed to focus on thermal issues where power is transported from the lower North Island to Whakamaru and Huntly under low hydro conditions.

It is unlikely that the North Island will have enough generation capacity to meet demand, even with a northward flow during the winter peak load when hydro generation is comparatively low. Therefore, the dry condition winter peak load is scaled down to 97% to comply with the system condition assumptions.

## 3.3 Contingencies under intact network conditions (N-1)

### 3.3.1 Assumptions

The following assumptions were made for the N-1 and voltage stability studies.

- Penrose 220 kV series reactor is normally bypassed. However, the bypass can be opened to reduce the loading on the North Auckland and Northland (NAaN) cable for planned outages.
- Slack bus is Huntly 220 kV for NS3/NS4 and Haywards 220 kV for all other system conditions, this is applicable for voltage stability studies as well.
- Reactive power loading of STATCOMs is maintained at minimum value as much as possible pre contingently.
- All assets mentioned in Appendix A: Grid configurations are assumed to be available for operation.
- To maintain a conservative approach, not all shunt capacitors are switched on for the voltage stability studies. Therefore, additional shunts in upper North Island can be utilized, if necessary, to enhance the voltage stability load limit without violating the steady-state voltage limits.

### 3.3.2 Low upper North Island thermal generation (NS1 and NS2)

For HVDC north transfer, a notable network challenge is the power flow through central North Island to supply electricity to the Auckland area, as well as Hamilton, Hawke's Bay, and Taranaki regions. Several circuits on the North Island's 220 kV grid limit inter-regional power transfer, both under normal and planned outage conditions, especially with low thermal generation in the WUNI. For certain scenarios, HVDC north transfer and North Island generation must be constrained to prevent overloading certain key circuits. These constraints change as grid conditions, such as planned outages or customer load, vary.

Wind generation generally contributes 20% and 25% of its maximum active power output in summer and winter, respectively. Sensitivity analysis considers wind output at 80% of its maximum. Solar generation is assumed to contribute 0% during winter peak and 25% capacity factor during summer peak.

Hydro, geothermal, and all other thermal generation (including Stratford peakers and Taranaki Combined Cycle)[1] are maximised to meet the winter peak demands. During the 80% wind sensitivity analysis, thermal generation is curtailed to accommodate wind generation. In the summer peak scenario with 80% wind sensitivity analysis, Huntly units 5 and 6 are the only thermal generation dispatched.

Upper North Island generation is limited to 350 MW (Huntly unit 5 at 300 MW, Glenbrook cogeneration at 40 MW and Ngawha B at 10 MW) during the winter peak and 310 MW during the summer peak. Winter peak load is scaled down to 96% and increased wind generation to 30% in 2027

[1] *In other Grid Zones (6 and 8), sensitivity scenarios have been included where these generators are not available.*

winter case due to insufficient firm capacity to maintain NS1 assumptions. The Ruakaka and Glenbrook BESS each dispatched 25 MW during peak conditions.

Winter peak load remains unchanged in the 80% wind sensitivity studies of 2027 as generation issues are mitigated by high wind output. This underscores potential thermal and voltage limit violations with the forecasted winter peak load in 2027.

Geothermal generation is maximized, while hydro and other thermal generation (excluding Taranaki Combined Cycle) are dispatched to meet the summer peak demands.

Constraints within the central North Island (CNI) and lower North Island (LNI) 220 kV network, namely, Tokaanu, Whakamaru and Wairakei Ring constraints, are detailed in this section.

For HVDC north transfer, Table 3-3 outlines the circuits that limit inter-regional power transfer on the North Island backbone if tripped under an intact network scenario. Table 3-3 also outlines the operational measures and constraint for each contingency.

Table 3-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measures | Additional Notes |
|---|---|---|---|---|
| HAM-WKM-1 220 kV circuit, HLY-SFD-1 220 kV circuit | Overload of BPE-MTR-1 110 kV circuit. | Winter 2025 | BPE-MTR Circuit Overload Protection Scheme operates and mitigates the overloading. | Additional 50 MW generation from Ruakaka and Glenbrook BESS resolve this. Further this will be resolved by the "Ongarue 110 kV split" committed project in June 2026. |
| HLY-TWH-1, SFD-TMN-1 or TMN-TWH-1 220 kV circuits | Overload of HLY-SFD-1 220 kV circuit where the binding constraint is BPE-MTR-1 110 kV circuit. | Winter 2025 | Constrain the HVDC North flow or Taranaki generation in 2025. | Additional 5 0MW generation from Ruakaka and Glenbrook BESS resolve this. Further this will be resolved by the "HLY-SFD protection upgrade" committed project in June 2026. |
| TKU-WKM-1 or 2 220 kV circuits | Overload of the remaining TKU-WKM 220 kV circuit. | Winter 2025. | TKU Circuit Overload Protection Scheme operates and mitigates the overloading. | Thermal violation of TKU-WKM-2 will be resolved by "Thermal upgrade of TKU-WKM 2", committed project in June 2026<br>However, Thermal upgrade of TKU-WKM 1 is planned in June 2027. |
| TKU-WKM-2 220 kV circuit | Overload of TKU-WKM-1 220 kV circuit. | Winter 2027. | TKU Circuit Overload Protection Scheme operates and mitigates the overloading. | Thermal violation of TKU-WKM-1 will be resolved by "Thermal upgrade of TKU-WKM 1", committed project in June 2027. |

| Contingency | Effect of Contingency | Scenario | Operational Measures | Additional Notes |
|---|---|---|---|---|
| MTI-WKM-1 220 kV circuit | Overload of the remaining MTI-WKM-2 220 kV circuit. | All seasons, all years depending on the MTI generation. | MTI Runback Scheme operates and mitigates the overloading. | Happens during high MTI generation. |

Table 3-4 outlines the circuits that limit inter-regional power transfer on the North Island backbone with 80% wind generation in addition to the circuits stated in Table 3-3 if tripped under an intact network scenario.

Table 3-4: Summary of contingencies during high wind scenarios under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measures | Additional Notes |
|---|---|---|---|---|
| HLY-SFD-1 or HAM-WKM-1 220 kV circuit | Overload of MTR-OKN-1 and BPE-MTR-1 110 kV circuits. | Winter 2025, high wind. | BPE-MTR Circuit Overload Protection Scheme operates and mitigates the overloading. | This will be resolved by the “Ongarue 110 kV split” committed project in June 2026. |
| PAK- WKM-2, BPE-TNG-1, RPO-WRK-1, BPE-WIL-LTN-1, OHW-WKM-1 or BPE-TKU-1 or 2 220 kV circuits | Overload of BPE-MTR-1 110 kV circuit. | Winter 2025, high wind. | BPE-MTR Circuit Overload Protection Scheme operates and mitigates the overloading. Constrain the HVDC North flow to avoid the overloading till June 2026. | There are various contingencies that overloads the BPE-MTR-1 110 kV circuit and HLY-TWH-1 220 kV will be the most binding contingency. This will be resolved by the “Ongarue 110 kV split” committed project in June 2026. Further, Additional 50 MW generation from Ruakaka and Glenbrook BESS will resolve the overloading of PAK-WKM-2 220 kV. |
| HLY-TWH-1, SFD-TMN-1 or TMN-TWH-1 220 kV circuits | Overload of HLY-SFD-1 220 kV, BPE_MTR-1 and MTR-OKN-1 100kV circuits. Overload of TKU-WKM- 2 220 kV | Winter 2025, high wind. | BPE-MTR Circuit Overload Protection Scheme operates and mitigates the overloading. | Overloading of HLY-SFD-1 can be resolved by the “HLY-SFD protection upgrade” committed project in June 2026. |

| Contingency | Effect of Contingency | Scenario | Operational Measures | Additional Notes |
|---|---|---|---|---|
| | circuit where the binding constraint is BPE-MTR-1 110 kV circuit. | | Constrain the HVDC North flow to avoid the overloading. | |
| TKU-WKM-1 or 2 220 kV circuits | Overload of the remaining TKU-WKM 220 kV circuit and BPE-MTR-1 110 kV circuit. | Winter 2025, high wind. | BPE-MTR Circuit Overload Protection Scheme operates and mitigates the overloading of BPE-MTR -1 110 kV circuit. Constrain the HVDC North flow when high Wind generation. | Although TKU Circuit Overload Protection Scheme operates it is not sufficient to mitigate the overloading of the TKU-WKM other 220 kV circuit due to high active power flow from HAY to UNI. |
| TKU-WKM-2 220 kV circuit | Overload of TKU-WKM-1 220 kV circuit. | Winter 2027, high wind. | Constrain the HVDC North flow during high wind generation. | However, thermal violation of TKU-WKM-1 will be resolved by TKU-WKM 1 thermal upgrade committed project in June 2027. |

### 3.3.3 HVDC south transfer (NS3 and NS4)

HVDC south transfer presents a significant network issue with power flow into the Wellington region. There are several bottlenecks on the North Island 220 kV grid that limit inter-regional power transfer, both under intact network conditions and under planned outage conditions. In certain scenarios, HVDC south transfer and North Island generation must be constrained to prevent overloading some key circuits. These constraints vary as grid conditions, such as planned outages or customer load, change.

Contribution of wind generation is 20% of the maximum active power output. Sensitivity analysis was carried out with 5% wind generation for NS3 and NS4 to observe the additional network constraints that can be experienced while pushing more power towards lower North Island under extreme low wind generation, especially for voltage stability. Solar generation contribution is assumed to be 0% during the winter and 25% during the summer peak. Hydro, Geothermal and all other thermal generation are maximized to meet the peak demand. The system slack bus has been set at Huntly 220 kV in both studies.

Sensitivity with Taranaki Combined Cycle (TCC) retirement was studied in last SSF. However, no confirmation was received in the Security of Supply Annual Assessment survey regarding the retirement. Hence, TCC has been dispatched for this system condition. Chapters for Grid Zone 6 and Grid Zone 8 studied the impact should TCC retire and become unavailable.

With 20% wind generation, no short-term thermal violations or voltage violations have been observed during the south flow. However, the Rangipo-Tangiwai-1 220 kV circuit was loaded to 97% of its 15-min offload loading for the Bunnythorpe-Tokaanu 220 kV contingency. Therefore, under this condition, HVDC south flow must be constrained below 500 MW during the winter peak. Few thermal violations could be observed with the reduction of wind generation to 5% from 20% (wind generation reduced by 163 MW) for certain contingencies. For HVDC south transfer, Table 3-5 outlines the circuits that limit inter-regional power transfer on the North Island backbone if tripped under an intact network scenario. Table 3-5 also outlines the operational measures and constraint for each contingency.

Table 3-5: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measures |
|---|---|---|---|
| BPE-TKU-1 or 2 220 kV circuits | Overload of RPO-TNG-1 and BPE-TNG-1 220 kV circuits. | All years with very low wind generation. | Constrain the generation from central North Island to reduce HVDC south flow. |
| TKU-WKM 1 or 2 220 kV circuits | TKU Circuit Overload Protection Scheme operates, overload of RPO-TNG-1 220 kV circuit. | All years with very low wind generation. | Constrain the generation from central North Island to reduce HVDC south flow. |

Grid Zone 8 studies found that Rangipo-Tangiwai-1 220 kV will be overloaded without TCC during high DC south transfers and low wind, even under intact conditions. Therefore, DC south transfer needs to be significantly constrained under the no TCC scenario to maintain thermal limitations under intact and N-1 contingencies if wind generation is significantly low.

### 3.3.4 North Island grid voltage control during light load (NS5)

During very light load periods (particularly overnight in summer), the power flowing through the long transmission circuits in the North Island is significantly reduced, causing these circuits to become more capacitive in nature. This situation can result in high voltages across the upper North Island.

The effect of light load conditions on the 220 kV North Island backbone was studied with the summer 2024 trough load. Huntly Unit 5 was the only thermal unit dispatched. The contribution of wind generation is 20% of the maximum active power output. All available reactors and STATCOMs are in service to manage the over voltage issues, and available assets can be found in Appendix A: Grid Configuration.

#### *3.3.4.1 Light load observations*

The worst system conditions for high voltage issues occur during summer light load periods with all transmission assets in service:

- Low North Island load (e.g. summer night trough load)
- Low upper North Island generation
- Maximum geothermal in the Bay of Plenty and central North Island
- Low central North Island hydro generation
- No Taranaki or Huntly generation

- No wind generation in the lower and central North Island regions
- Low HVDC transfer (typically < 200 MW)

#### *3.3.4.2 Summary of transmission voltage issues*

Te Kowhai and Taumarunui 220 kV bus voltages were high during the Huntly-Te Kowhai 220 kV circuit contingency, however, voltages are within Code limits.

#### *3.3.4.3 Mitigation options*

Currently high voltages are managed via the following operational measures to ensure secure system operation. These include:

- Utilisation of SVC/STATCOM within its maximum capability
- Switching out capacitor banks
- Switching in the reactors
- Dispatching generation to absorb reactive power
- Switching out certain 220 kV circuits as last option

In the previous SSF, it was found that several transmission circuits would need to be removed from service to mitigate over-voltages in Grid Zone 1 and Grid Zone 2. With the completion of the two 100 Mvar Pakuranga reactors and the Hamilton STATCOM, significant over-voltage issues have not been observed for current and future light load conditions. Furthermore, with the commissioning of the Ōtāhuhu STATCOM, these over-voltage issues could be entirely mitigated. However, if overvoltage issues are seen at Te Kowhai and Taumarunui 220 kV buses for the contingency, some transmission circuits may need to be switched out to reduce the voltage.

### 3.3.5 North Island dry condition (NS6)

This system condition presents a network issue with potential low hydro generation in North Island, which may arise due to dry condition. There are several bottlenecks on the North Island 220 kV grid that limit inter-regional power transfer under intact network conditions.

Hydro generation has been limited based on historic operational data to simulate a dry condition. Contribution of wind generation needs to be increased to meet the winter peak load, with the limited hydro generation. Solar generation contribution is assumed 0% during the winter peak. All available other generation has been dispatched around 95% percentile.

For HVDC north transfer during North Island dry condition, Table 3-6 outlines the circuits that limit inter-regional power transfer on the North Island backbone when tripped during an intact network scenario. Table 3-6 also outlines the operational measures and constraint for each contingency.

Table 3-6: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measures | Additional Notes |
|---|---|---|---|---|
| HLY-SFD-1, HLY-TWH-1, SFD-TMN-1 or TMN-TWH-1 220 kV circuits | Overload of BPE_MTR-1 110 kV circuit. | All years. | BPE-MTR Circuit Overload Protection Scheme operates and mitigates the overloading. | This will be resolved by the "Ongarue 110 kV split" committed project in June 2026. |

If wind generation is low, it will become security of supply issue with the North Island dry condition during winter peak rather than thermal issues.

## 3.4 Voltage stability studies

The upper North Island region is defined as the area encompassing Grid Zones 1 and 2, the Auckland and Northland regions and includes Huntly power station. The region is supplied by 220 kV and 110 kV transmission circuits from the southern part of the North Island. The upper North Island is a large load centre in the North Island comprising approximately 45% of North Island winter/summer peak load with limited local generation. Huntly is the only large generating station in the upper North Island. High HVDC north transfer can be a potential operational scenario with the expected upper North Island generation displacement.

The 220 kV circuits originate from Stratford, Te Kowhai, Ohinewai and Whakamaru buses in the Edgecumbe and Taranaki regions. The 110 kV circuits originate from the Arapuni and Hamilton buses in the Waikato region.

Capacitor banks are available at Hamilton, Ōtāhuhu, Penrose, Henderson, Albany and Hepburn Road substations. A Static Var compensator (SVC) is installed at Albany and STATCOMs are installed at Hamilton, Penrose and Marsden substations with a future STATCOM planned for Ōtāhuhu 220 kV substation.

The upper North Island region is shown geographically in Figure 3-3.


Figure 3-3 Geographic representation of Upper North Island

### 3.4.1 Definitions

The voltage stability limit for the upper North Island is defined as the maximum pre-contingency real power that can be transferred into the upper North Island to avoid voltage collapse after the loss of a key power system component.

The amount of real power transferred into the region is defined as the sum of real power flowing on the 220 kV and 110 kV circuits into the region, namely:

- Pakuranga-Whakamaru 1 and 2 220 kV circuits
- Huntly-Stratford 1 220 kV circuit
- Huntly-Te Kowhai 1 220 kV circuit
- Huntly-Ohinewai 1 and 2 220 kV circuits
- Ohinewai-Ōtāhuhu 1 and 2 220 kV circuits
- Ōtāhuhu-Whakamaru 1 and 2 220 kV circuits.

- Arapuni-Bombay 1 110 kV circuit

These circuits are shown where the black dashed line crosses them in the single line diagram in Figure 3-4.

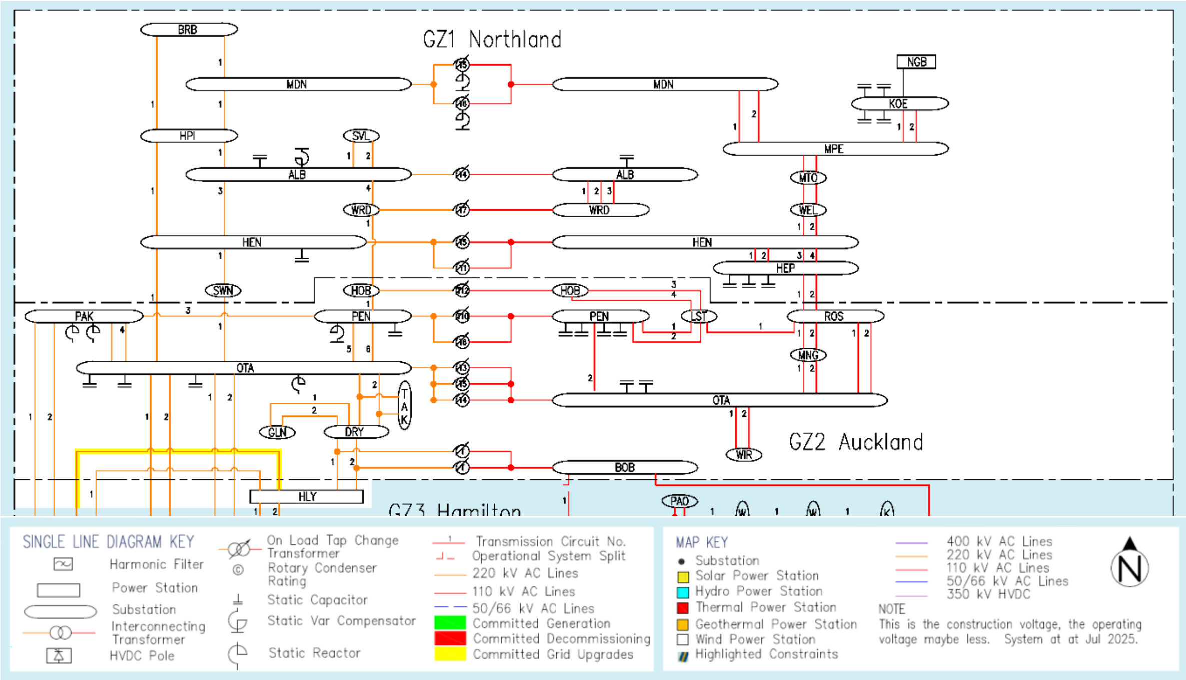


Figure 3-4: Single line diagram of upper North Island

Note that the voltage stability transfer limit ignores all assets overloading in the rest of the North Island. Voltage stability is limited by the first bus where voltage collapse occurs.

The thermal transfer limit considers the post contingent loading of circuits, maintaining the asset loading within their rated capability.

Voltage stability studies have been carried out for N-1 conditions during winter and summer. Demand forecast, reactive plant availability and generation capability are as stated in Appendix A: Grid Configuration. Some key voltage stability terms used in this study are defined below.

- Voltage stability transfer limit is the pre-contingent transfer limit on the circuits into the Upper North Island before voltage collapse.
- Voltage stability load limit is the pre-contingent load limit in the Upper North Island before voltage collapse.
- Thermal transfer limit is the pre-contingent transfer limit on the circuits into the Upper North Island with all transmission circuits loaded within rated capability.
- Thermal load limit is the pre-contingent load limit in the Upper North Island with all transmission circuits loaded within rated capability.

### 3.4.2 Voltage stability limits

The following permanent voltage stability constraint has been published to the market to indicate the voltage stability limit in the upper North Island:

Constraint Name: UPPER_NORTH_ISLAND_STABILITY_1E

Constraint Equation: -1 * HLY_OHW1.1 + -1 * HLY_OHW2.1 + -1 * HLY_SFD.1 + -1 * HLY_TWH1.1 + 1 * OHW_OTA1.1 + 1 * OHW_OTA2.1 + -1 * OTA_WKM1.1 + -1 * OTA_WKM2.1 + -1 * PAK_WKM1.2 + -1 * PAK_WKM2.2 + 1 * ARI_BOB1.1 <= Limit

The voltage stability transfer limits in table 3-7 show the indicative limit for the permanent voltage stability constraint stated above that would be applicable for the scenarios studied. In real-time operations, the limit is determined using online voltage stability analysis tools.

#### *3.4.2.1 Contingencies under intact network conditions (N-1)*

Table 3-7 and Table 3-8 show the transfer and load limits into the upper North Island under intact network conditions in winter and summer. The circuit tripped is referred to as a contingency.

Table 3-7: Upper North Island transfer and load limits under N-1 winter conditions.

| Contingency | Scenario | Voltage Stability Transfer Limit (MW) | Voltage Stability Load Limit (MW) | Thermal Transfer Limit (MW) | Thermal Load Limit (MW) |
|---|---|---|---|---|---|
| HLY U5 | Winter | 2171 | 2432 | NA | NA |
| HLY-SFD-1 220 kV circuit | Winter | 2251 | 2505 | NA | NA |
| HLY-TWH-1 220 kV circuit | Winter | 2207 | 2464 | NA | NA |
| PAK-WKM-1 220 kV circuit | Winter | 2421 | 2657 | NA | NA |
| OTA C29 (100MVar) | Winter | 2356 | 2625 | NA | NA |

The most limiting contingency is the loss of Huntly 5 generation in winter due to the reactive support it provides to the upper North Island region. The combined North Island Grid Zone1 and Grid Zone 2 winter peak load is 2440 MW in 2025. The voltage stability load margin is slightly higher than the winter peak load for a Huntly 5 contingency. The voltage stability load limit could be further improved by switching additional capacitors and fully utilizing the reactive power capacity of the Hamilton and Otahuhu STATCOM. The voltage stability load margin will be improved to 2462 MW from 2432 MW for the Huntly 5 contingency with the commissioning of the Otahuhu STATCOM.

The cabled section of the Pakuranga-Whakamaru 2 220 kV circuit will not be available from June 2024 for approximately two year period. However, the Ohinewai deviation will be in service during this period. The study has been conducted with this outage and the voltage load stability limit is reduced from 2363 MW to 2349 MW. However, Ruakaka BESS active power injection will enhance the voltage stability margin during this period. Hence, maintaining voltage stability during this outage will be worse. Implementing operational measures such as generation agreements and load management will be required.

Table 3-8: Upper North Island transfer and load limits under N-1 summer conditions.

| Contingency | Scenario | Voltage Stability Transfer Limit (MW) | Voltage Stability Load Limit (MW) | Thermal Transfer Limit (MW) | Thermal Load Limit (MW) |
|---|---|---|---|---|---|
| HLY U5 | Summer | 1969 | 2236 | NA | NA |
| HLY-SFD-1 220 kV circuit | Summer | 2148 | 2402 | 2027 | 2291 |
| HLY-TWH-1 220 kV circuit | Summer | 2142 | 2396 | 2027 | 2291 |
| PAK-WKM-1 220 kV circuit | Summer | 2159 | 2412 | 2027 | 2291 |
| OTA C29 (100MVar) | Summer | 2237 | 2482 | 2027 | 2291 |

In summer, the most limiting contingency is the loss of Huntly 5 generation due to the reactive support it provides to the upper North Island. The upper North Island summer peak load in 2024 is 1715 MW. This is lower than the voltage stability load limit for the contingency of Huntly 5. Bunnythorpe-Mataroa-1 110kV circuit overloads in all above contingencies except for HLY 05 before reaching the voltage stability load margins. However, thermal load limits are adequately higher than the summer peak load.

Voltage stability load limits for upper North Island will be improved from 2026 onwards with the commissioning of the Ōtāhuhu STATCOM. Voltage load stability limit is well above the forecasted summer peak in 2026. However, voltage load stability limit is around 95% of the 2027 forecasted winter peak load for most worst contingency. Hence, will require operational measures which involves increasing load generation and/or managing load.

# 4 South Island grid backbone

## 4.1 Grid backbone overview

The New Zealand power system consists of two separate networks (one in the North Island and one in the South Island) which are connected via an HVDC link. The backbone of the power system is a 220 kV network that spans the length of both islands. The bi-directional HVDC link is connected at Haywards in the North Island and Benmore in the South Island.

During daylight periods and with normal rainfall patterns in the South Island, power tends to flow from the South Island to the North Island. During non-peak periods, late evenings, early mornings, and in years of low South Island hydro lake storage levels, power can flow from the North Island to the South Island. However, during system peak loading conditions HVDC south transfer might not be achievable due to North Island transmission and generation constraints following the decommissioning of upper North Island thermal generation.

This section describes the contingencies affecting the South Island 220 kV grid backbone with a focus on inter-regional transfer. More details on regional issues can be found in the sections for each Grid Zone.

The South Island 220 kV grid backbone consists of the following circuits.

- 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 seven large hydro power stations and the HVDC link
- Three circuits from Roxburgh to Twizel and Livingstone in the Waitaki Valley area
- Four circuits from Roxburgh to Invercargill/North Makarewa, two via Three Mile Hill
- Nine circuits within the Southland area

The South Island 220 kV grid backbone is shown geographically in Figure 4-1 and as a single line diagram in Figure 4-2. Committed projects or upgrades are highlighted in yellow on the single line diagram.

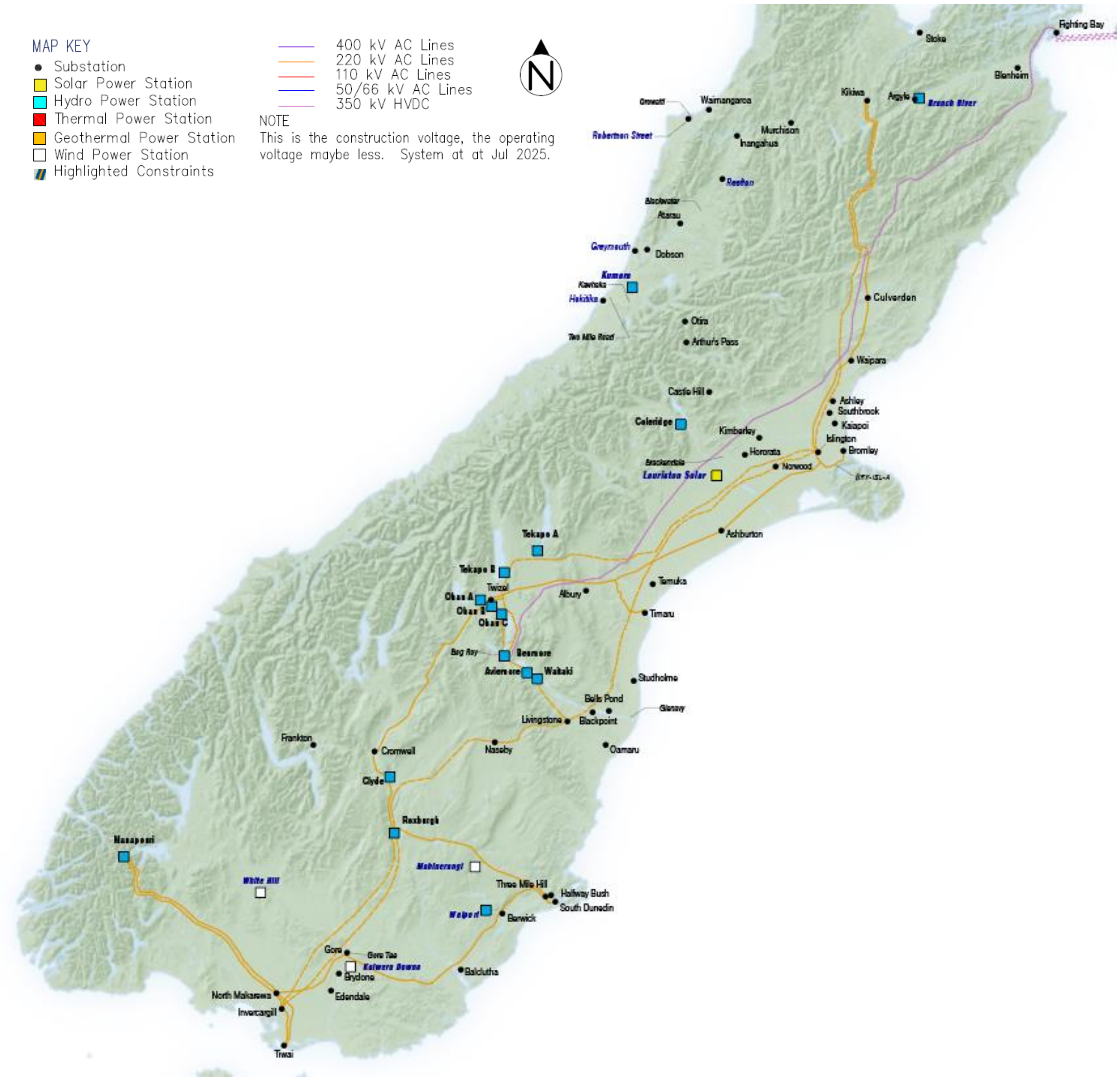


Figure 4-1: Geographic representation of South Island 220 kV grid backbone

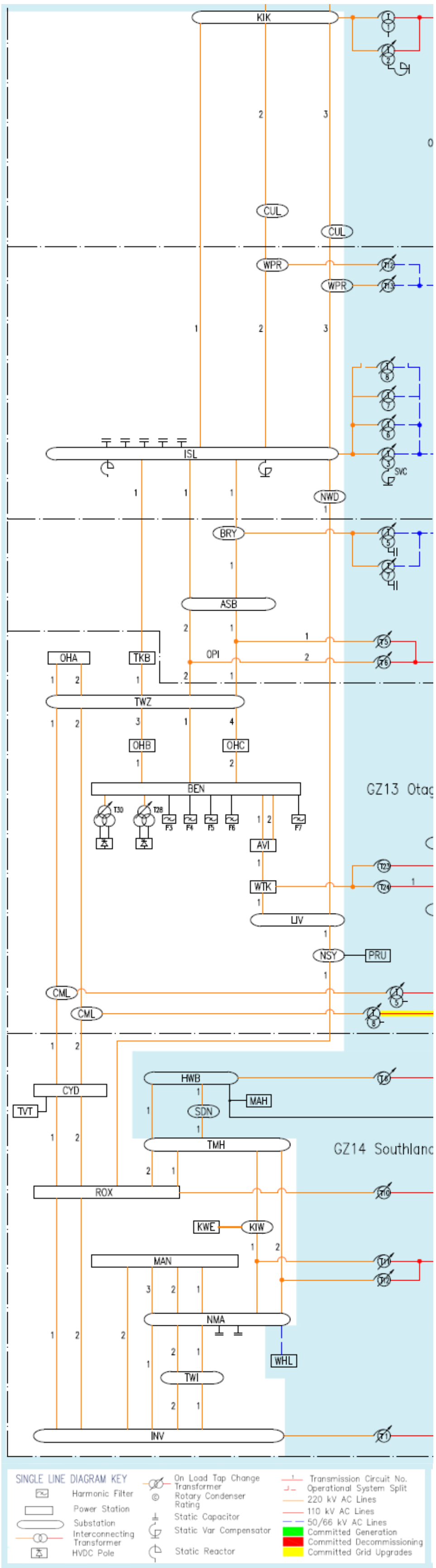


Figure 4-2: Single line diagram of South Island 220 kV grid backbone

### 4.1.1 Committed projects and upgrades

The committed projects and upgrades that impact the South Island grid backbone over the period of study are shown in Table 4-1 and Table 4-2 respectively.

Table 4-1: Committed projects in South Island

| Asset | Changes | Commissioning Date | Grid Zone |
|---|---|---|---|
| KAI-TF1 and TF2 branch limit | Upgrade the KAI-TF1 and TF2 11kV branch limit | Dec-2025 | 10 |
| Timaru 220/110 kV interconnecting Transformer Replacement | Timaru T8A and T8B replaced 1 x 250 MVA 10% Z Unit. | Commissioned | 11 |
| Frankton Supply Transformer Upgrade | Frankton T4, T2A and T2B supply transformers upgraded to 2 x 120 MVA, 10% Z units. | Commissioned | 13 |
| CML-FKN 110 kV circuit upgrade | Thermal upgrade of CML-FKN 1 & 2 circuits to 100degC to increase Frankton transmission capacity | April-2026 | 13 |
| INV 220/66 supply Transformer and 66 kV bus | New 66 kV bus and 220/66 kV supply transformer for Powernet at INV to support electrification in the area | Commissioned | 14 |

Table 4-2: Committed South Island generation upgrades

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date | Grid Zone |
|---|---|---|---|---|---|---|
| Lauriston (Genesis) | Canterbury | Solar | 47 | Ashburton | Commissioned | 11 |
| Kaiwera Downs Stage 2 (Mercury) | Southland | Wind | 152 | Kaiwera[2] | 2026 | 14 |

## 4.2 South Island system conditions

Thermal constraints of the grid depend on the dispatch of the generators. Thus, different generation scenarios can lead to various network constraints in both backbone and 110 kV network. Accordingly, seven possible generation scenarios (system conditions) have been identified to examine the system's capabilities and potential constraints in the system. In the grid backbone studies, network analyses have been conducted under these seven system conditions. The system conditions are listed and discussed below.

[2] *New Grid Injection Point- In and Out connection to North Makarewa and Three Mile Hill*

### 4.2.1 South Island system condition 1: upper South Island constraints during winter

South Island system condition 1 (SS1) tests very low generation in the upper South Island area during high winter peak. Although the upper South Island has low generation compared to demand, generation still has a noticeable effect on transmission constraints. It is designed to highlight transmission issues into the upper South Island from the Waitaki Valley area.

### 4.2.2 South Island system condition 2: upper South Island constraints during summer

South Island system condition 2 (SS2) tests very low generation in the upper South Island area during high summer peak. Although the upper South Island has relatively little generation compared to demand, generation still has a noticeable effect on transmission constraints. It is designed to highlight transmission issues into the upper South Island from the Waitaki Valley area. The main difference when compared to SS1 is the lower transmission line thermal ratings which can be significant for voltage stability limits.

### 4.2.3 South Island system condition 3: high generation export from the lower South Island during winter

South Island system condition 3 (SS3) tests the case where there is either significant generation exported from the lower South Island or a significant reduction in load in the lower South Island during winter. It tests the grid's ability to transmit surplus power from south of Roxburgh to large load centres in Christchurch and/or the North Island (HVDC). In the previous SSF, the potential exit of the Tiwai Smelter was studied. However, it has been projected that the Tiwai Smelter operations will continue throughout the study period as the load forecast reveals no signs of an impending exit.

### 4.2.4 South Island system condition 4: high generation export from the lower South Island during summer

South Island system condition 4 (SS4) tests the case where there is either significant generation exported from the lower South Island or a significant reduction in load in the lower South Island during summer. It tests the grid's ability to transmit surplus power from south of Roxburgh to large load centres in Christchurch and/or the North Island (HVDC). The main difference when compared to SS3 is the lower transmission line thermal ratings which can be significant for thermal limit violations. Also, Tiwai smelter remains throughout the study period.

### 4.2.5 South Island system condition 5: high import to the lower South Island during dry winter

South Island system condition 5 (SS5) tests very low generation in the lower South Island to represent low hydro inflows in the South Island during the winter. The balance of power flows into the lower South Island from generation in the Waitaki Valley or the North Island (represented by HVDC south flow). The aim of this assessment is to highlight system bottlenecks associated with power import into the lower South Island.

### 4.2.6 South Island system condition 6: high import to the lower South Island during dry summer

South Island system condition 6 (SS6) tests very low generation in the lower South Island to represent low hydro inflows in the South Island during the summer. The balance of power flows into the lower South Island from generation in the Waitaki Valley or the North Island (represented by HVDC south flow). The aim of this assessment is to highlight system bottlenecks associated with power import into the lower South Island. The main difference when compared to SS5 is the lower transmission line thermal ratings which can be significant for thermal limit violations.

### 4.2.7 South Island system condition 7: light load

South Island system condition 7 (SS7) tests the effect of low load on the grid backbone. Observations of a summer night, light load period where high voltage issues on the grid are a concern in the upper South Island have been discussed.

## 4.3 Contingencies under intact network conditions (N-1)

### 4.3.1 Assumptions

The following assumptions were made for the N-1 and voltage stability studies.

- Slack bus is Benmore 220 kV for all system conditions.
- The 110 kV Network is permanently split at Studholme, with Studholme supplied from Timaru in summer and Waitaki in winter.
- Reactive power loading of STATCOMs is maintained at minimum value as much as possible pre contingently.
- Tiwai assumed to be remaining in service for the duration of this study.
- All assets listed in Appendix A: Grid Configuration are assumed to be available for operation.

### 4.3.2 Upper South Island constraints (SS1 and SS2)

The upper South Island is defined as the area encompassing Grid Zones 9, 10, 11, and 12, which are the Nelson-Marlborough, Christchurch, Canterbury, and West Coast regions. It is a large load centre in the South Island with a limited amount of local generation. The region is supplied by 220 kV transmission circuits from the south. The 220 kV circuits originate from Twizel and Livingstone buses in the Otago region.

The upper South Island is shown geographically in Figure 4-4. No thermal or voltage limit violations were detected during these studies.

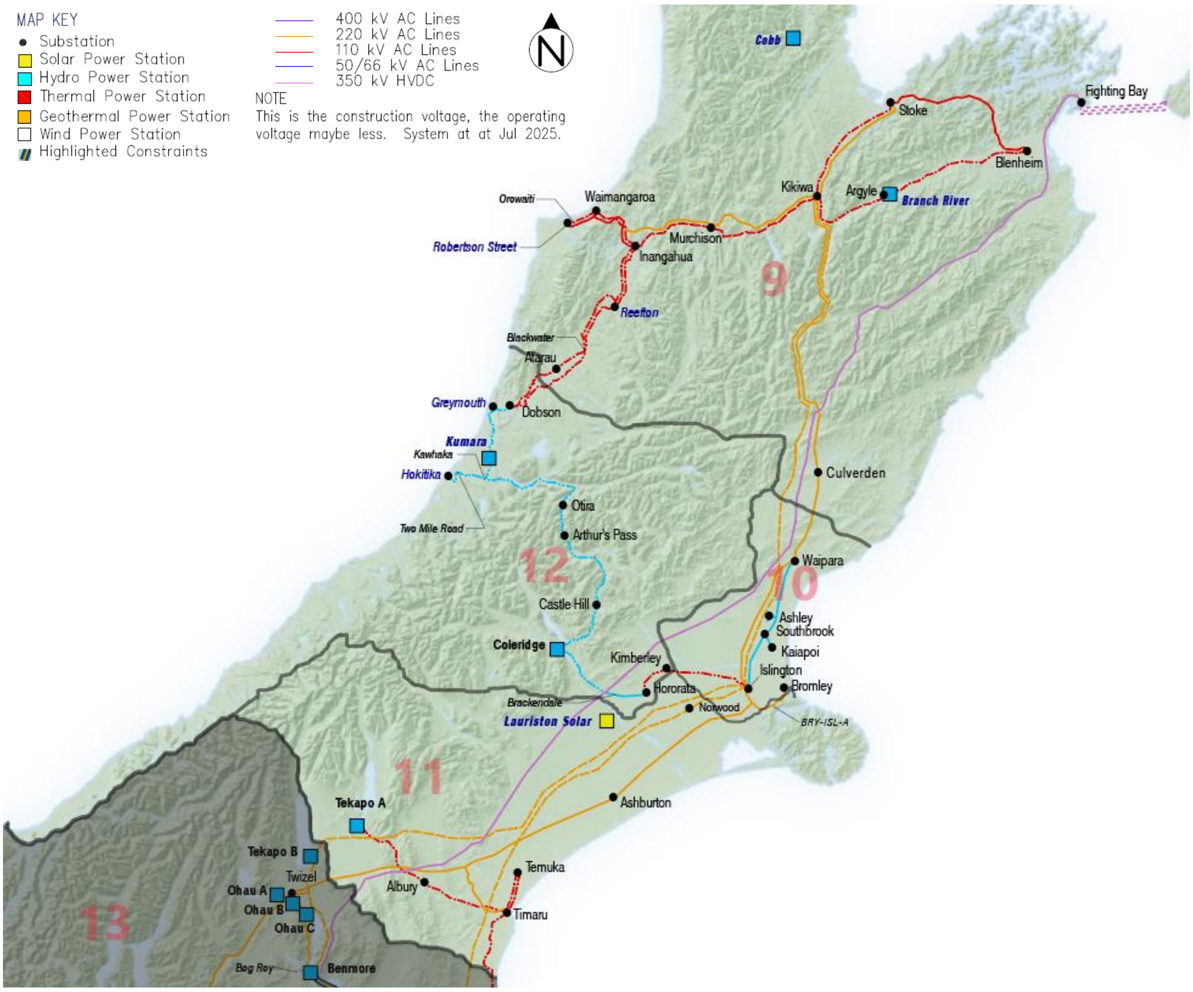


Figure 4-3: Geographic representation of upper South Island

### 4.3.3 High generation export from the lower South Island (SS3 and SS4)

The lower South Island consists of the area south of (and including) Clyde. There is approximately 1,952 MW of generation in the area, increasing to 2,107 MW following the commissioning of Kaiwera Downs Stage 2. This generation presently supplies local loads including Tiwai Aluminium Smelter and Dunedin city. The surplus generation is exported to the upper South Island and North Island via HVDC from three 220 kV circuits north of Roxburgh and Clyde. Power transfer out of the lower South Island is limited by the thermal capacity of these circuits.

Details of thermal issues that arise during periods of peak load and high lower South Island generation and the constraints required under intact network conditions are elaborated in sections 16 and 17 for Otago and Southland regions respectively.

Table 4-3 outlines the circuit that limits inter-regional power transfer on the South Island backbone network between the lower South Island and Waitaki Valley region if tripped under an intact network scenario. The table also outlines the operational measures or constraint for each contingency.

Table 4-3: Limiting contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measures |
|---|---|---|---|
| AVI-BEN-1 or 2 220 kV circuit | Overload of the remaining AVI-BEN 220 kV circuit. | Summer, 2025 onwards. | Managed post contingency by opening AVI-WTK with the AVI-BEN Circuit Overload Protection Scheme. |

### 4.3.4 High generation import into lower South Island during dry conditions (SS5 and SS6)

Hydro generation in New Zealand has limited storage. Extended periods of low inflows into hydro storage catchments can result in storage levels reaching a point where industry action is required to avert a need to ration electricity to consumers. Industry actions include the use of an official conservation campaign to minimise demand; running North Island thermal units at higher capacity factors and re-configuring the grid to maximise capacity for transferring electricity from thermal stations to demand centres.

In 2008 and 2012, hydro storage levels in the South Island reached thresholds where industry action was deemed appropriate. In early June 2017 South Island storage levels reached the 2% hydro risk curve[3]. In such dry year situations, South Island hydro storage can be preserved through transfer of power from the North Island via the HVDC link to help meet South Island demand.

This section describes constraints in the South Island network caused by low hydro generation. Many constraints for high HVDC south flow are in the North Island. Information on system constraints in the North Island network caused by high HVDC south transfer into the South Island can be found in sections 3, 11 and 12, discussing the North Island 220 kV Grid Backbone, Grid Zones 7 and 8 respectively.

For the purpose of examining South Island 220 kV grid backbone capability, the assumed HVDC south transfer levels might not be achievable due to North Island transmission constraints, demand and available generation. However, this study is conducted to highlight potential constraints concerning high power import into the lower South Island and the results are presented in this section as a reference. The following analysis used the South Island seasonal peak load, except for Tiwai Aluminium Point Smelter load which remained at approximately 572 MW. Further, under this condition, only two Manapouri generators, one Clyde generator, and two Roxburgh generators contribute to the lower South Island's generation.

Table 4-4 outlines the circuits that limit inter-regional power transfer on the South Island backbone network if tripped under an intact network scenario.

[3] *Hydro Risk Curves Explanation | Transpower*

Table 4-4 also outlines the operational measures or constraint for each contingency. This backbone constraint limits inter-regional transfers. Voltage stability of lower South Island under dry conditions, particularly Southland is captured in Section 17.5.

Table 4-4: Limiting contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| AVI-BEN-1 or 2 220 kV circuit | Overload of the remaining AVI-BEN 220 kV circuit. | Summer, all years. | Implement security constraint on transfer out of Benmore. | The AVI-BEN Circuit Overload Protection Scheme will not be available in this scenario as it only operates when power is flowing north. |

### 4.3.5 South Island grid voltage control at light load (SS7)

During very light load periods (particularly overnight), the power flowing through the long transmission circuits in the South Island is significantly reduced causing these circuits to become more capacitive in nature. This situation can result in high voltages across large areas of the upper South Island.

There are a range of operational measures taken to maintain South Island bus voltages within Code limits. In the South Island, high voltage issues are currently being adequately managed. However, in the absence of additional reactive compensation or operational measures being put in place in the future, managing high voltage issues may become more difficult.

#### *4.3.5.1 Light load observations*

The worst system conditions for high voltage issues typically occur during light load periods (night trough), with low HVDC transfer (typically less than 200 MW) and all transmission assets in-service. All available reactors and STATCOMs are in service to manage the over voltage issues, and available assets can be found in Appendix A: Grid Configuration.

#### *4.3.5.2 Summary of transmission voltage issues*

No voltage issues were detected during this study, however if issues were to occur during real time, the following mitigation measures would be available.

#### *4.3.5.3 Mitigation options*

Currently high voltages are managed via the following operational measures to ensure secure system operation. These include:

- Utilisation of SVC/STATCOM within its maximum capability
- Switching out capacitor banks
- Switching in the reactors

- Dispatching generation to absorb reactive power.
- Switching out certain 220 kV circuits as a last option

Occurrence of these high voltages could reduce over time if system demand at times of light load increases. However, if there is a reduction in the minimum loads or an increase in capacitive load power factor across the grid during light load periods, these issues may become unmanageable using current operational measures and reactive plant, which will require permanent solutions.

## 4.4 Voltage stability studies

Static capacitors are installed at Blenheim, Stoke, Islington, Southbrook, Greymouth and Hokitika substations. Static Var Compensators (SVC 3 and SVC 9) are installed at Islington and a STATCOM is installed at Kikiwa.

The upper South Island is shown geographically in Figure 4-4.

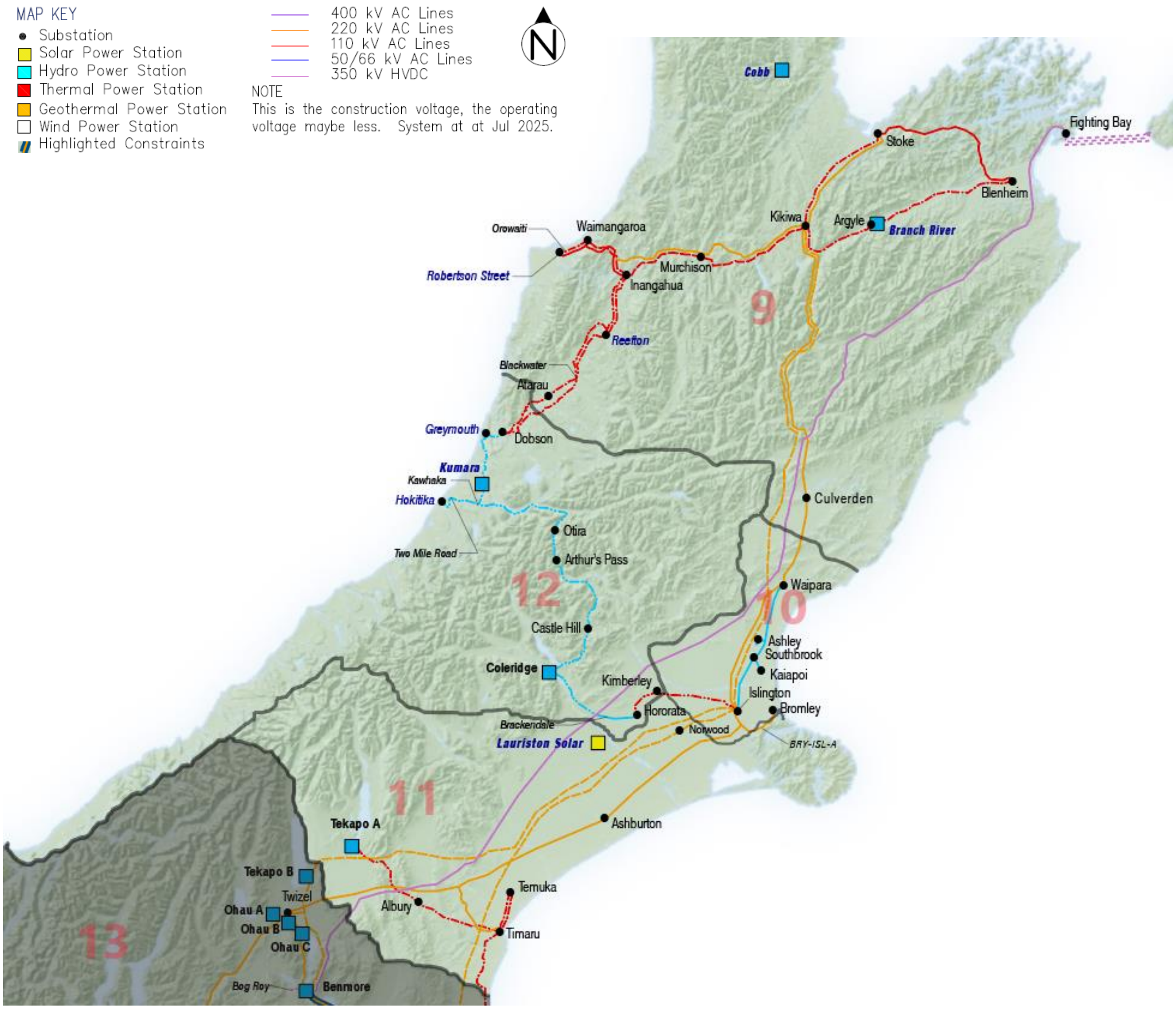


Figure 4-4: Geographic representation of upper South Island

The voltage stability studies in the SSF considered N-1 conditions during winter and summer. Load forecast, reactive plant availability and generation capability are as stated in Appendix A: Grid Configuration.

## 4.4.1 Definitions

The voltage stability limit for the upper South Island is defined as the maximum pre-contingent real power that can be transferred into the upper South Island and avoid voltage collapse after the loss of a key power system component. The amount of real power transferred into the region is defined as the sum of real power flowing on the 220 kV circuits into the region, as follows:

- Livingstone-Norwood 1 220 kV circuit
- Ashburton-Timaru-Twizel 1 and 2 220 kV circuits
- Islington-Tekapo B 1 220 kV circuit.

The circuits are shown in the single line diagram in Figure 4-5. The transfer interface is represented by the pink dashed line below.

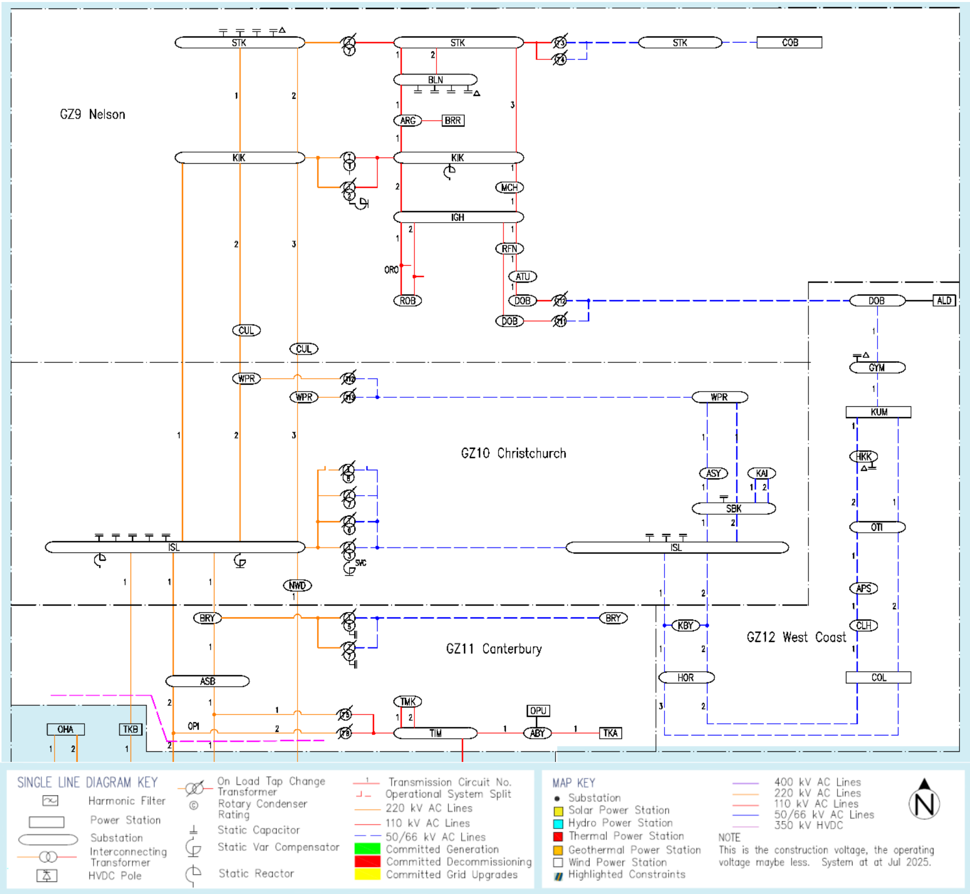


Figure 4-5: Single line diagram of upper South Island

The voltage stability transfer limit ignores all asset overloading in the rest of the South Island. Voltage stability is limited by the first bus where voltage collapse occurs.

The thermal transfer limit considers the post contingent loading of circuits, maintaining the asset loading within their rated capability. Voltage stability studies have been carried out for N-1 conditions during winter and summer under SS1 and SS2 system conditions. Demand forecast, reactive plant availability and generation capability are as stated in Appendix A: Grid Configuration report. Some key voltage stability terms used in this study are defined below.

- Voltage stability transfer limit is the pre-contingent transfer limit on the circuits into the Upper South Island before voltage collapse.
- Voltage stability load limit is the pre-contingent load limit in the Upper South Island before voltage collapse.
- Thermal transfer limit is the pre-contingent transfer limit on the circuits into the Upper South Island with all transmission circuits loaded within rated capability.
- Thermal load limit is the pre-contingent load limit in the Upper South Island with all transmission circuits loaded within rated capability.

### 4.4.2 Voltage stability limits

The following permanent voltage stability constraint has been published to the market to indicate the voltage stability limit in the upper South Island:

| | |
|---|---|
| Constraint Name: | UPPER_SOUTH_ISLAND_STABILITY_P_1B |
| Constraint Equation: | -1 * ASB_TIM_TWZ2.3 + -1 * ISL_TKB.1 + -1 * LIV_NWD.1 + -1 * ASB_TIM_TWZ1.3 <= Limit |

The voltage stability transfer limits in Table 4-5 show the indicative limit for the permanent voltage stability constraint equation stated above that would be applicable for the scenarios studied. In real-time operations the limit is determined more accurately using online voltage stability analysis tools.

#### *4.4.2.1 Contingencies under intact network conditions (N-1)*

In winter, the loss of Islington-Tekapo B 1 220 kV circuit is the most limiting contingency while in summer the loss of either Ashburton-Timaru-Twizel 1 or 2 220 kV circuit is the most limiting contingency. The 110 kV Network is permanently split at Studholme, with Studholme supplied from Timaru in summer and Waitaki in winter.

A number of sensitivity studies were conducted to determine the impact of varying generation, reactive power sources, and seasons on voltage stability limits.

The load limit is the sum of the loads in Grid Zones 9, 10, 11 and 12.

Table 4-5: Upper South Island voltage stability transfer and load limits under varying conditions

| Most Limiting Contingency | Season | Transfer Limit (MW) | Load Limit (MW) |
|---|---|---|---|
| ISL-TKB 1 220 kV circuit | Winter | 1402 | 1372 |
| ASB-TIM-TWZ 1 or 2 220 kV circuit | Summer | 1283 | 1260 |

The load forecast is 1295 MW for winter peak 2027 and 1145 MW for summer peak 2026, both of which are considerably lower than the load limits. Therefore, there is no foreseen issues with managing the upper South Island load under intact network conditions during the forecast period.

# 5 Grid Zone 1

## 5.1 Network overview

Grid Zone 1 is at the top of the North Island and includes all circuits and stations north of and including Hepburn Road on the 110 kV network and Southdown on the 220 kV network.

Grid Zone 1 has 220/110 kV interconnecting transformers at Marsden, Albany, and Henderson. There are capacitors at Albany, Henderson, and Hepburn Road substations and two STATCOMs at Marsden to improve network voltage and voltage stability.

As there is a low amount of grid-connected generation in the region, the regional demand is effectively supplied via double circuits from the Ōtāhuhu station, the Mount Roskill station, and the 220 kV North Auckland and Northland (NAaN) cable from Penrose station.

The Northland region is shown geographically in Figure 5-1 and the single line diagram in Figure 5-2.

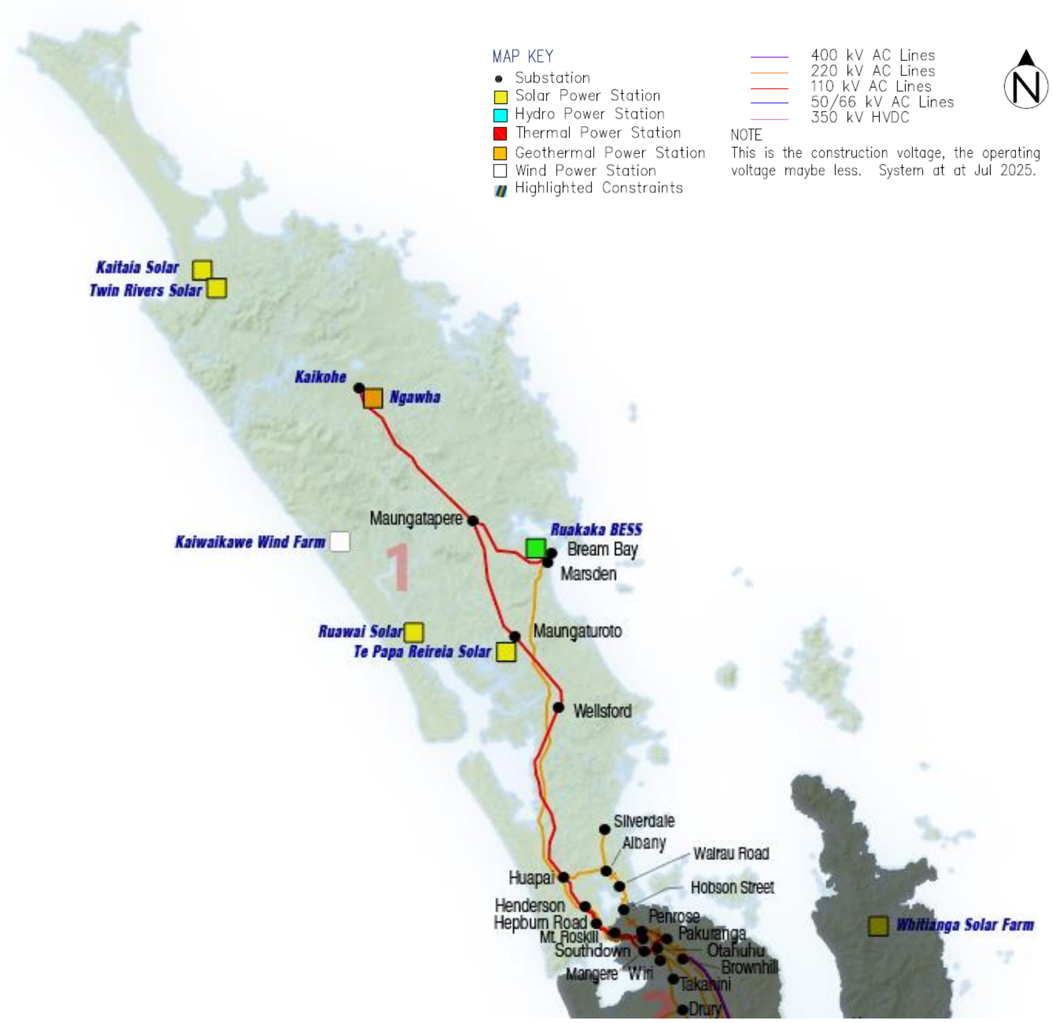


Figure 5-1: Geographic representation of Grid Zone 1

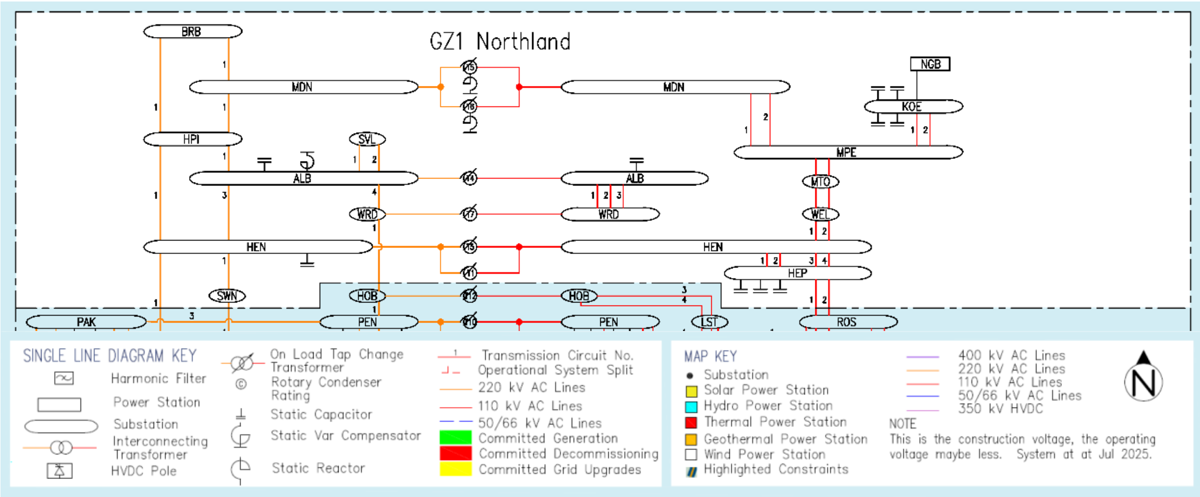


Figure 5-2: Grid Zone 1 Single Line Diagram

## 5.2 Committed projects and upgrades

The committed grid and generation/storage projects in the Grid Zone over the period of study are shown in Table 6-1 and Table 6-2 respectively.

Table 5-1: Summary of committed grid upgrades

| Asset | Changes | Commissioning Date |
|---|---|---|
| Wairau Road second Transformer (T9) | Install WRD T9 220/110 kV, 250 MVA transformer | September-2026 |

Table 5-2: Summary of committed generation/storage

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|---|
| Ruakaka BESS (Meridian) | Northland | Battery | +/-100 MW, 200 MWh | Bream Bay | Commissioned |
| Twins Rivers (Ranui Generation Limited) | Northland | Solar | 24 | Kaitaia/Kaikohe | 2026 |
| Pukenui (Aquila Clean Energy) | Northland | Solar | 17.1 | Kaikohe | Commissioned |
| Ruawai (Northpower Limited) | Northland | Solar | 14 | Maungaturoto | Commissioned |
| Te Papa Reireia (Maungaturoto Solar Farm Project LP) | Northland | Solar | 17.6 | Maungaturoto | 2025 |
| Kaiwaikawe Wind Farm (Mercury) | Northland | Wind | 70 | Maungatapere | 2026 |

## 5.3 Assumptions and background

The following assumptions were made for Grid Zone 1 studies, unless otherwise specified separately:

- In N-1 studies, all Huntly units are assumed to be out of service for light load studies. In winter and summer peak scenarios, Huntly units 1, 2, and 4 are assumed to be out of service.
- In voltage stability studies, Huntly units 1, 2, 4, and 5, Ngawha A and Ngawha B are assumed to be out of service during winter and summer peak studies.
- Reactive power loading of SVCs and STATCOMs are maintained at minimum value as much as possible pre contingently.
- All capacitors offered by the grid owner were assumed to be available to support voltage during peak loads.
- HEP-ROS 110 kV Overload Protection Scheme is available, normally enabled.
- PEN Reactor Bypass Scheme is available, normally enabled.
- Albany and Wairau Road GXPs are tied through the Vector network.
- Two of the three Wairau Road 110/33 kV transformers are in-service to manage fault levels.
- Ōtāhuhu-Penrose 2 110 kV circuit is removed from service to manage Vector Network flows.
- Penrose 220 kV series reactor is normally bypassed. However, the bypass can be opened to reduce the loading on the NAaN cable for planned outages.
- Ruakaka BESS was assumed not to provide voltage support in the steady state.
- The following scenarios were studied for N-1:
  - NS1 - HVDC North Flow Low HLY at Winter Peak (including high hydro generation and high wind).
  - NS2 - HVDC North Flow Low HLY (including low hydro generation, but no wind or solar sensitivity).
  - NS5 - Summer Trough load (including high solar and low wind).

## 5.4 Contingencies under intact network conditions (N-1)

Table 5-3 shows the interconnecting transformer that would cause network violations if tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 5-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| ALB T5 220/110 kV interconnecting transformer | Overloads WRD T7 220/110 kV interconnecting transformer | Winter, all years | Load management at Wairau Road to reduce the loading on this interconnecting transformer. Possible options include a second 220/33 kV supply transformer at Wairau Road | ALB ICTs are considered as ECE[4] with no issues found. This requires a review of the event classification. **Comment (June minor update):** Proposed WRD T9 220/110 kV ICT in Sep 2026 will solve the overloading of WRD T7. |

## 5.5 Overvoltage analysis during light load

Some transmission circuits can become very lightly loaded, particularly overnight in summer. When circuits are lightly loaded this can cause overall system voltage to rise across the upper North Island (UNI). The System Operator aims to dispatch dynamic reactive plant on the system below its maximum operating point so that a degree of headroom is available to both regulate the network voltage and provide additional support in the event of a contingency in the region. Often local generation voltage support capability is insufficient to manage all high voltage situations alone and additional actions are taken. No overvoltage issues were detected in Grid Zone 1 during this study, with the completion of the two 100 Mvar Pakuranga reactors, Hamilton STATCOM.

In the previous SSF, it was found that several transmission circuits will be required to be removed from service to mitigate any over voltages in Grid Zone 1 and Grid Zone 2. With the completion of the two 100 Mvar Pakuranga reactors, Hamilton STATCOM, and in the future the Ōtāhuhu STATCOM, there wasn't a need to switch out any of the transmission circuits during light load.

## 5.6 Voltage stability studies

The voltage stability of upper North Island is discussed in the North Island Backbone in section 3.4. The upper North Island covers both Grid Zone 1 and 2. Being a large load centre with limited local

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[4] *Under N-1 conditions, HAM T6 and T9 have ECE event classification, as per the Credible Event Review 2024. (https://www.transpower.co.nz/system-operator/information-industry/operational-information-system/event-categorisation ).*

generation, the upper North Island voltage stability is managed by the System Operator by applying a permanent voltage stability constraint. There is no particular voltage stability constraint applied to Grid Zone 1, but the voltage stability is monitored in real time operations.

No voltage stability issues were identified within the range of the study period. The voltage stability load limits were above the load forecast with adequate margin. The study also considered without Huntly Unit 5 and Ngawha A and B in service but required all reactive plants in Grid Zone 1 and Zone 2 to be utilized including Hamilton STATCOM.

# 6 Grid Zone 2

## 6.1 Network overview

Grid Zone 2 is in the upper North Island (UNI) and represents the Auckland region. The region is supplied by 220 kV transmission circuits from the south with interconnecting transformers at Ōtāhuhu, Penrose, Hobson Street, and Bombay substations. The 220 kV circuits originate from Huntly, Ohinewai, and Whakamaru buses. The 110 kV circuits that supply Bombay substation originate from the Arapuni and Hamilton buses in the Waikato region. In addition to supplying Auckland regional load, the 220 kV transmission circuits supply the Northland region.

Capacitor banks are available at Ōtāhuhu and Penrose substations, and a STATCOM is located at Penrose substation. Reactors are available in Pakuranga and Ōtāhuhu substations.

The Auckland region is shown geographically in Figure 6-1 and as a single line diagram in Figure 6-2.

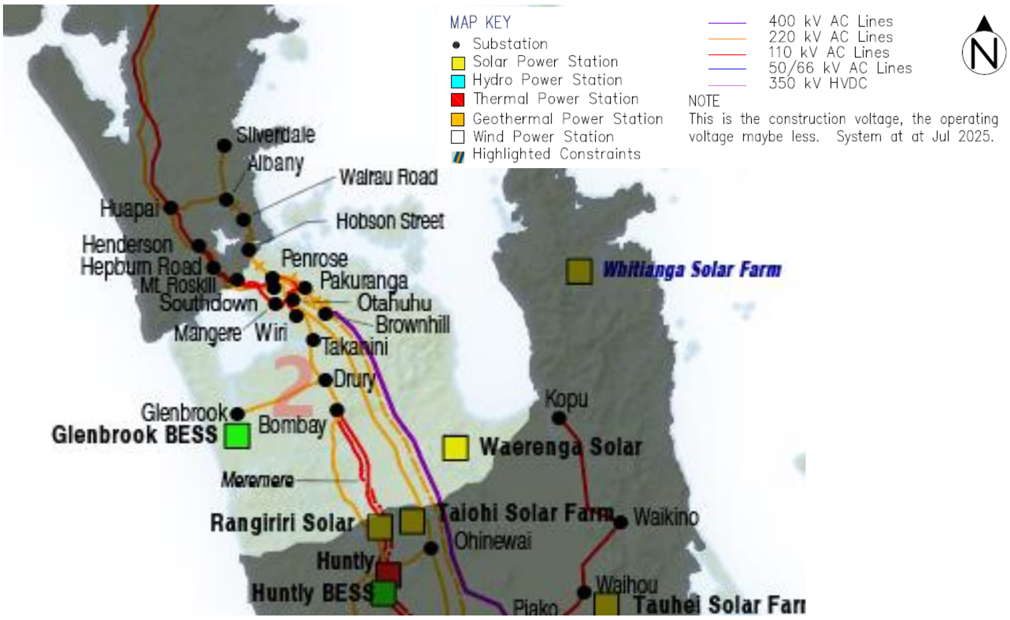


Figure 6-1: Geographic representation of Grid Zone 2

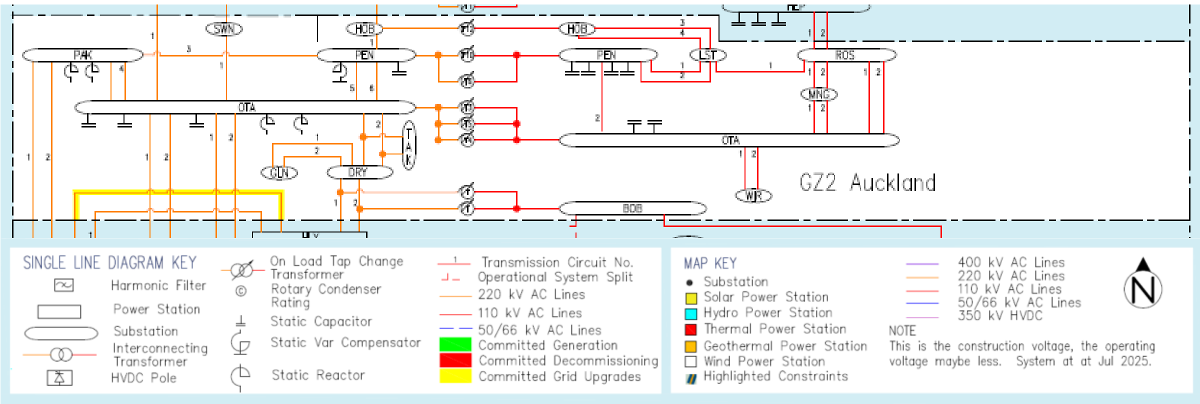


Figure 6-2: Grid Zone 2 Single Line Diagram

## 6.2 Committed projects and upgrades

The committed grid and generation projects in the Grid Zone over the period of study are shown in Table 6-1 and Table 6-2 respectively.

Table 6-1: Summary of committed grid upgrades

| Asset | Changes | Commissioning Date |
|---|---|---|
| Bombay GXP | BOB-HAM-1 110 kV circuit disconnected. | Commissioned |
| Ōtāhuhu STATCOM | Install a 150 Mvar STATCOM at Ōtāhuhu 220 kV | Commissioned |
| Glenbrook STATCOM (Contact Energy) | Installation of a 74 MVAr STATCOM on Glenbrook 33kV dirty bus to support voltage variations caused by the new arc furnace load. | December-2025 |

Table 6-2: Summary of committed generation

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|---|
| Waerenga Solar Farm (Island Green Power Ltd) | Auckland | Solar | 190 | Awariki Road (new) | 2027 |
| Glenbrook BESS | Auckland | Battery | +/-100 MW, 200 MWh | Glenbrook | 2025 |

## 6.3 Assumptions and background

The following assumptions were made for Grid Zone 2 studies, unless specified separately:

- For the light load studies, all Huntly units are assumed to be out of service.
- Reactive power loading of SVCs and STATCOMs are maintained at minimum values as much as possible pre contingently.

- NZ Steel's STATCOM at Glenbrook is primarily used to manage the voltage fluctuations caused by a new arc furnace load and not primarily used for grid voltage support.
- HEP-ROS 110 kV Overload Protection scheme is available, normally enabled.
- Penrose Reactor Bypass Scheme is available, normally enabled.
- Hobson Street and Penrose GXPs are tied through the Vector network.
- Albany and Wairau Road GXPs are tied through the Vector network.
- Two of the three Wairau Road 110/33 kV transformers are in-service to manage fault levels.
- Ōtāhuhu-Penrose 2 110 kV circuit is available but normally opened at the Ōtāhuhu end.
- Penrose 220 kV series reactor is normally bypassed.
- The cable section of Pakuranga-Whakamaru 2 220 kV circuit is on planned outage from June 2024 until June 2026. The Ohinewai deviation will be in service during the planned outages.
- The following scenarios were studied for N-1:
  - NS1 - HVDC North Flow Low HLY at Winter Peak (including high hydro generation and high wind).
  - NS2 - HVDC North Flow Low HLY (including low hydro generation, but no wind or solar sensitivity).
  - NS5 - Summer Trough load (including high solar and low wind).

## 6.4 Contingencies under intact network conditions (N-1)

Table 6-3 shows the transmission circuits that would cause network violations within Grid Zone 2 if tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 6-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| PAK-WKM 1 or 2 220 kV circuits | Overload of both OTA-HTP-WKM 220 kV circuits | Winter peak, 2026 onwards | Post contingent loading of HTP-WKM 220 kV circuits are less than the short-term thermal overload capability (OTA-WKM 220 kV thermal ratings was applied). Hence, no operational measures required. | This contingency was also studied in the voltage stability analysis of the upper North Island in NI backbone chapter. |

# 7 Grid Zone 3

## 7.1 Network overview

Grid Zone 3 is the area bordered by and including Kopu in the north and Kinleith in the south. The load is supplied by 220 kV and 110 kV transmission circuits and generation within the region, with 220/110 kV interconnecting transformers at Hamilton.

Significant generators in the region include Huntly, Karapiro and Arapuni.

The bus at Arapuni is typically split to allow generation at Arapuni to be maximised as described in Section 7.3 below.

The Hamilton Region is shown geographically and as a single line diagram in Figure 7-1 and Figure 7-2 respectively.

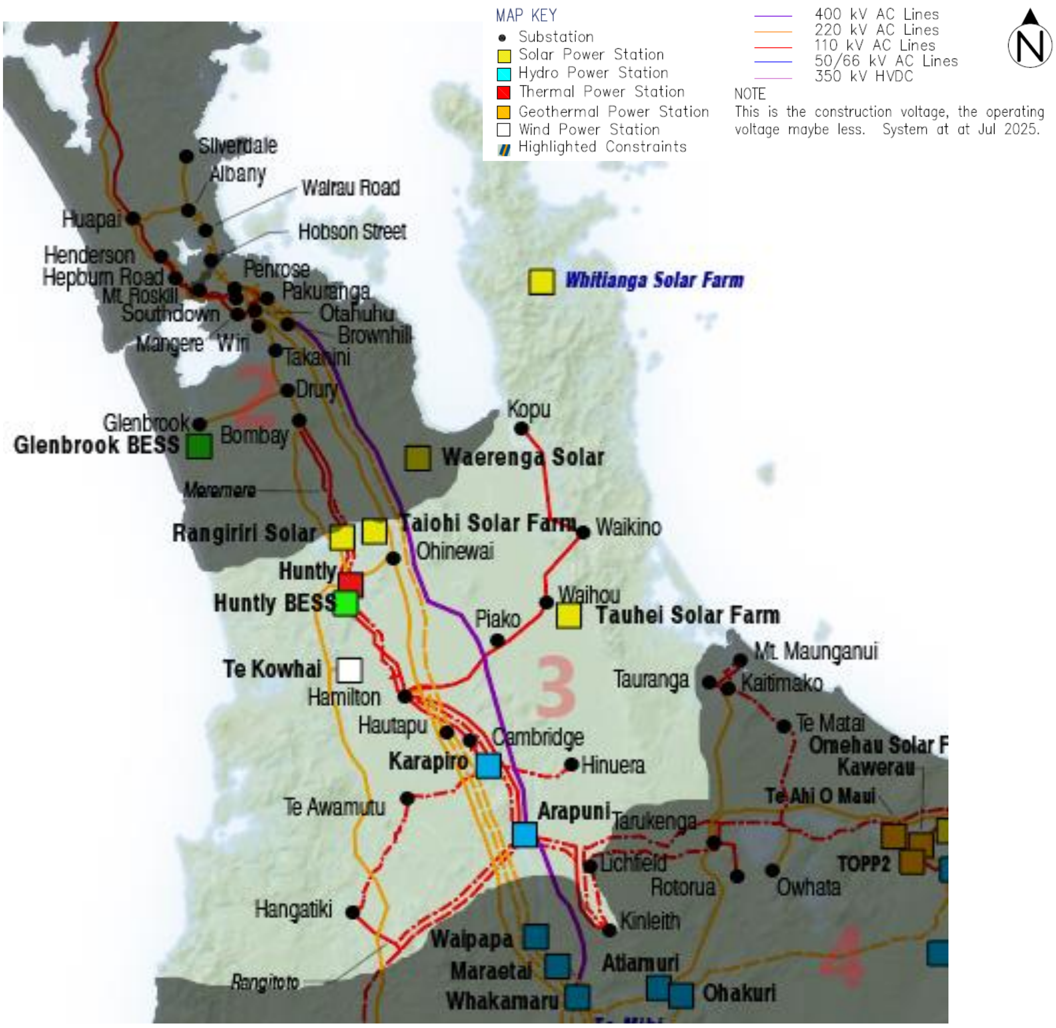


Figure 7-1: Geographic representation of Grid Zone 3

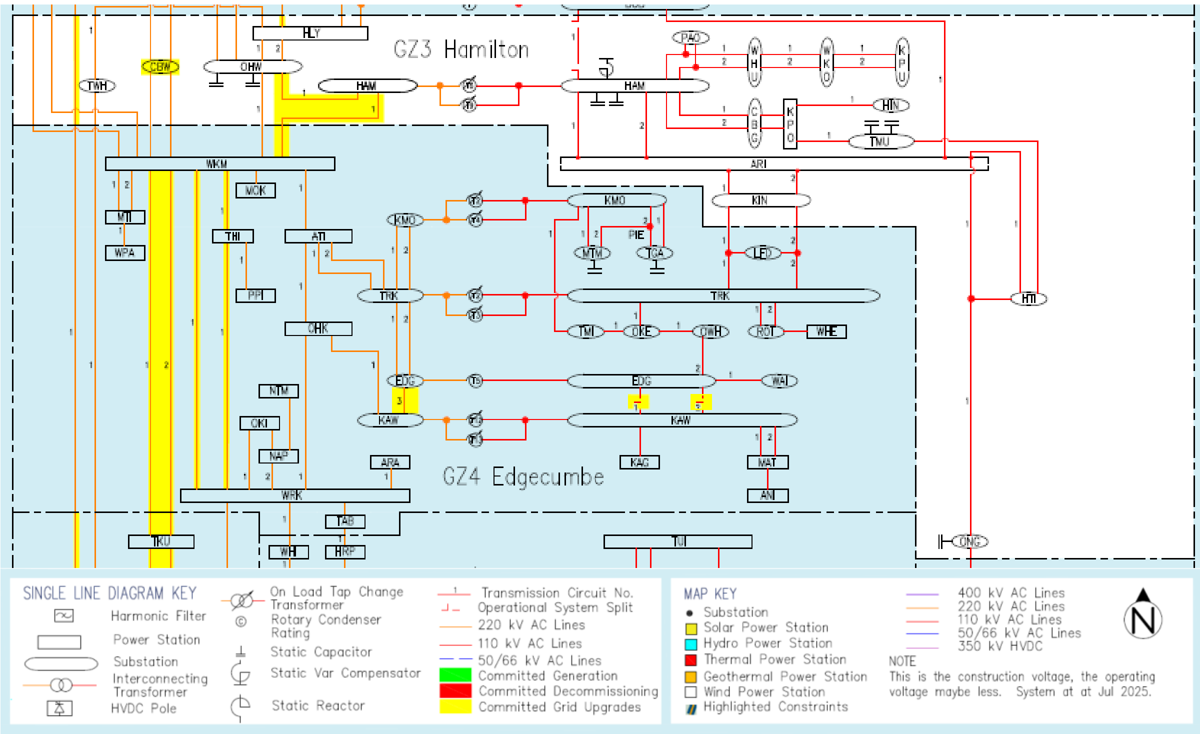


Figure 7-2: Single line diagram of Grid Zone 3

## 7.2 Committed projects and upgrades

The committed grid upgrades in the Grid Zone over the period of study are shown in Table 7-1. The committed generation projects are shown in Table 7-2.

Table 7-1: Summary of committed grid upgrades

| Asset | Changes | Commissioning Date |
|---|---|---|
| Hamilton–Whakamaru and Ohinewai–Whakamaru 220 kV circuits | Implement variable line ratings on the Hamilton–Whakamaru and Ohinewai–Whakamaru circuits | March-2027 |
| Hautapu GXP | New 220 kV GXP commissioned at Cambridge West, supplied from Ōtāhuhu–Whakamaru–1 and 2 circuits | Commissioned |
| Huntly–Stratford 220 kV circuit | NZGP Stage 1 - Remove line protection static limit on the Huntly–Stratford circuit | April-2026 |

Table 7-2: Summary of committed generation

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|---|
| Karapiro (Mercury) uprating of G1-G3 | Hamilton | Hydro | 112 | Karapiro | Commissioned |
| Tauhei Solar Farm | Hamilton | Solar | 150 | Waihou | 2026 |
| Whitianga Solar farm (Lodestone) | Hamilton | Solar | 23.75 | Kopu | 2026 |

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|---|
| Rangiriri Solar Farm (Island Green Power Ltd) | Hamilton | Solar | 146.7 | Glen Murray Road (new) | 2027 |
| Taiohi Solar Farm | Hamilton | Solar | 22.4 | Huntly | 2026 |
| Huntly BESS | Hamilton | Battery | +/-100 MW, 200 MWh | Huntly | 2026 |

## 7.3 Assumptions and background

The following assumptions were made for Grid Zone 3 studies, unless specified otherwise:

- Arapuni bus has been split with Arapuni circuit breaker 48 (ARI CB 48) open.
- ARI North Runback Scheme is available, normally enabled. The scheme is disabled until 19th October 2024 (end of the winter rating season), or until the upgraded scheme is fully commissioned, whichever comes first.
- ARI South Runback Scheme is available, normally enabled.
- Bombay 110 kV System Split Intertrip Scheme has been withdrawn from March 2023.
- ARI-KIN Overload Protection Scheme is available, normally disabled.
- ARI-HTI Circuit Overload Protection Scheme is available, normally disabled.
- HTI Supply Transformer Overload Protection Scheme is available, normally enabled.
- CBG Supply Transformer Overload Protection Scheme is available, normally enabled.
- When the Cambridge West GXP is commissioned, it is assumed that load will be split equally between that and the existing Cambridge GXP.
- Bombay-Hamilton 1 110 kV circuit de-energized from December 2023.
- Hydro generation is a significant factor in the N-1 study for Grid Zone 3. The following scenarios have been studied:
    - NS1 - HVDC North Flow Low HLY at Winter Peak (including high hydro generation, and 80% wind).
    - NS2 – HVDC North Flow Low HLY (including low hydro generation, but no wind or solar sensitivity).
    - NS6 – Dry Winter Peak.

Contingencies under intact network conditions (N-1)Table 7-3 shows the circuits/transformers that would cause network violations within Grid Zone 3 if tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 7-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| ARI-KIN-1 or 2 110 kV circuit | Overload of the remaining ARI-KIN 110 kV circuit. | All Winter years, Summer 2024, High ARI south generation when ARI bus is split. | Enable ARI South Runback Scheme. | When overloads are detected on either ARI-KIN-1 or 2 110 kV circuit, the scheme reduces generation from ARI South. If the overload persists after the generation reduction, the scheme subsequently trips ARI G7 and G6 at one second intervals. |
| HAM-PAO-WHU-1 or HAM-PAO-WHU-2 110 kV circuits | Overload of the remaining HAM-PAO-WHU 110 kV circuit. | Winter 2027 | Load management at PAO and WHU. | The 2023 TPR proposes a HAM-PAO-WHU circuit overload protection scheme possibly by 2027. |
| HAM T6 or T9 220/110 kV interconnecting transformers | Overload remaining HAM 220/110 kV interconnecting transformer. | Winter 2027, low Grid Zone 3 110 kV hydro generation. | Increase KPO or ARI generation during peak. Otherwise, especially dry hydro scenarios, apply load management at GXPs in GZ 03. | HAM ICTs are considered as ECE[5] with no issues found. This requires a review of the event classification. |
| HLY-TWH-1 or TMN-TWH-1 220 kV circuits | Overload of HLY-SFD-1 220 kV circuit. | Winter 2025, high wind. | Implement security constraints to increase HLY generation. | Resolved by the committed project in 2026 that removes the protection static limit on HLY-SFD-1 220 kV circuit. |
| HAM-KPO-1 or 2 110 kV circuit | Overload of CBG T3 or T4 110 kV supply transformers. | Summer 2024, low KPO generation, All years before Hautapu GXP. | CBG Supply Transformer Overload Protection Scheme sheds some load at CBG. Implement security constraints to increase generation from KPO after the SPS operation. | Remaining HAM-KPO 110 kV circuit does not overload. |
| HAM-KPO-1 or 2 110 kV circuit | Overload of the remaining HAM-KPO 110 kV circuit. | Winter 2027, low KPO generation. | Implement security constraints to increase generation from KPO. | CBG Supply Transformer Overload Protection Scheme does not operate. |

[5] *Under N-1 conditions, HAM T6 and T9 have ECE event classification, as per the Credible Event Review 2024. (https://www.transpower.co.nz/system-operator/information-industry/operational-information-system/event-categorisation ).*

# 8 Grid Zone 4

## 8.1 Network overview

Grid Zone 4 is in the centre of the North Island. The 220 kV circuits are bordered by Whakamaru on the north and Wairakei on the south, the 110 kV circuits supply the Bay of Plenty. There are 220/110 kV interconnecting transformers at Kaitimako, Tarukenga, Kawerau, and Edgecumbe. During normal operation, the Edgecumbe interconnecting transformer is open on the 110 kV side.

The Edgecumbe Region is shown geographically and as a single line diagram in Figure 8-1 and Figure 8-2.

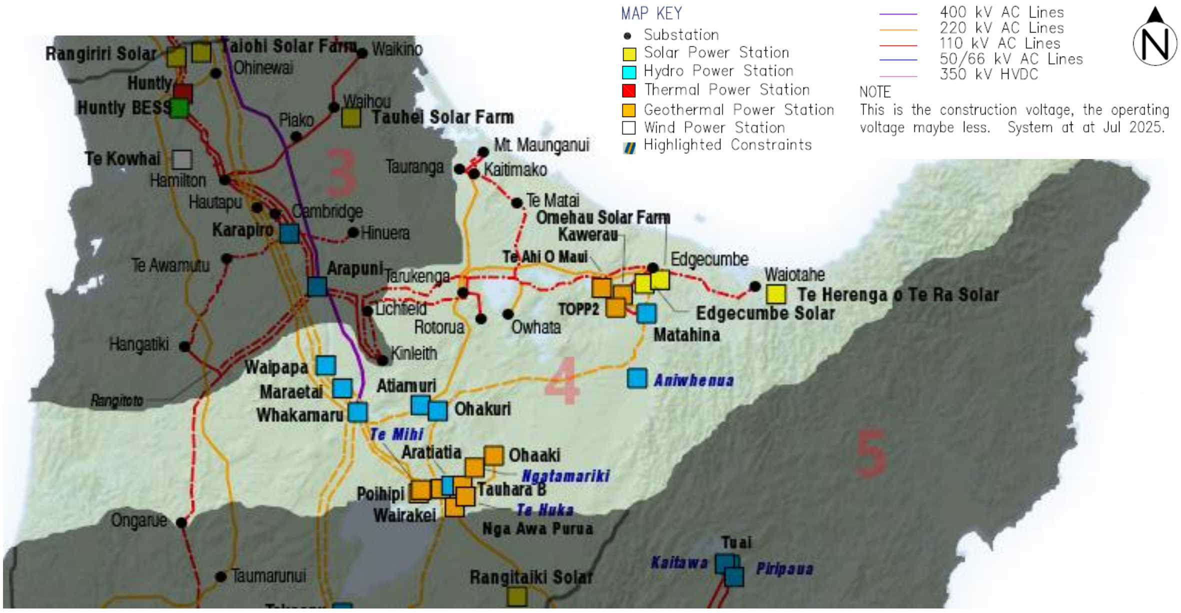


Figure 8-1: Geographic representation of Grid Zone 4

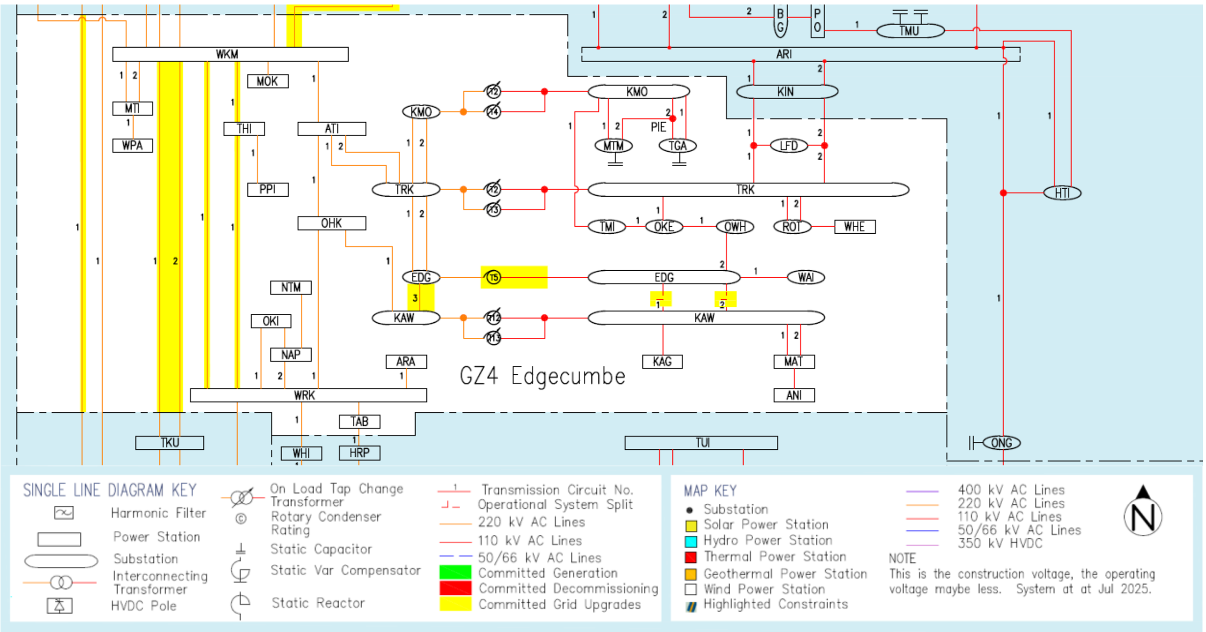


Figure 8-2: Single line diagram of Grid Zone 4

## 8.2 Committed projects and upgrades

The committed grid upgrades in the Grid Zone over the period of study are shown in Table 8-1. The committed generation projects are shown in Table 8-2.

Table 8-1: Summary of committed grid upgrades

| Asset | Changes | Commissioning Date |
|---|---|---|
| Kawerau 220/110 kV Interconnecting Transformer Replacement | Replace Kawerau–T13 with a 250 MVA transformer. | Commissioned |
| Lichfield–Tarukenga–1 110 kV Circuit | Reconductor 2 km section on the Lichfield–Tarukenga–1 circuit. | Commissioned |
| Tokaanu–Whakamaru 220 kV circuits | NZGP Stage 1 - thermal upgrade of the Tokaanu–Whakamaru 220 kV circuits with variable line ratings. | 2026 |
| Te Matai Supply Transformer | Replace Te Matai T1 with an 80 MVA transformer. | December-2025 |
| Te Mihi–Wairakei, Te Mihi–Whakamaru and Wairakei–Whakamaru 220 kV circuits | NZGP Stage 1 - Thermally upgrade the Wairakei–Whakamaru C line. (Te Mihi–Wairakei, Te Mihi–Whakamaru and Wairakei–Whakamaru circuits) | 2026 |
| Edgecumbe–Kawerau 3 220 kV circuit | NZGP Stage 1 - Thermally upgrade the Edgecumbe–Kawerau 3 220 kV circuit. | August-2026 |
| Tokaanu–Whakamaru 220 kV circuits | NZGP Stage 1 - Duplex the Tokaanu–Whakamaru 1 and 2 220 kV circuits. | June-2026, June-2027 |
| Wairakei Supply Transformer | Wairakei T29 and T30 capacity increased from 50MVA to 60MVA | December-2025 |
| Edgecumbe T5 Transformer Replacement | Replace EDG-T5 with old KAW-T13 | December-2026 |
| Edgecumbe-Kawerau 110kV split | Split the 110 kV: New N/O Kawerau CB172 & CB112 to Edgcumbe and close Edgecumbe CB292 to Edgecumbe T5. | Commissioned |

Table 8-2: Summary of committed generation

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|---|
| Te Herenga o Te Ra Solar Farm (Lodestone Energy Limited) | Edgecumbe | Solar | 35 | Waiotahe | Commissioned |
| Te Huka Geothermal (Contact) | Edgecumbe | Geothermal | 51 | Tauhara | Commissioned |
| Edgecumbe Solar (Helios Energy Limited) | Edgecumbe | Solar | 115 | Edgecumbe | 2026 |
| TOPP2 | Edgecumbe | Geothermal | 55 | Kawerau | Dec 2025 |
| Te Ahi O Maui | Edgecumbe | Geothermal | 27.4 | Kawerau | Commissioned |
| Ngatamariki OEC 05 | Edgecumbe | Geothermal | 54 | Nga Awa Purua | Dec 2025 |

## 8.3 Assumptions and background

The following assumptions were made for Grid Zone 4 studies, unless specified otherwise.

- KMO Intertrip Scheme is available, normally enabled.
- TKU Circuit Overload Protection Scheme is available, normally enabled.
- THI Generation Intertrip Scheme is available, normally disabled.
- EDG-KAW 1-2 Overload Protection Scheme is available, normally enabled.
- EDG-OWH 2 110 kV Overload Protection Scheme is available, normally enabled.
- KAW T13 Overload Protection Scheme is available, normally enabled.
- ~~A permanent split is applied at Edgecumbe Interconnecting transformer T5 to maintain N-1 security on Edgecumbe-Kawerau 1 and 2 110 kV circuits.~~
- MTI Runback Scheme is available, normally enabled.
- Arapuni 110 kV bus has been split on circuit breaker (CB) 48.
- ARI South Runback Scheme is available, normally enabled.
- ARI-KIN Overload Protection Scheme is available, normally disabled.
- The following scenarios have been studied:
  - NS1 - HVDC North Flow Low HLY at Winter Peak (including high hydro generation and high wind).
  - NS2 – HVDC North Flow Low HLY (including low hydro generation, but no wind or solar sensitivity).
  - NS5 – Summer Trough load (including high solar and low wind)
  - NS6 - Dry Winter Peak (With low wind and no solar sensitivity)

## 8.4 Contingencies under intact network conditions (N-1)

Table 8-3 shows the circuits/transformers that would cause network violations within Grid Zone 3 if tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the contingency's effect.

Table 8-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| EDG-KAW-3 110 kV circuit | Overload of EDG-OWH-2 and OKE-OWH-1 110 kV circuits. | All seasons, all years, high Grid Zone 4 generation. | EDG-OWH 2 110 kV Overload Protection Scheme operates. | |
| ~~EDG-KAW-1 or 2 110 kV circuits~~ | ~~Overload of the remaining EDG-KAW 110 kV circuit.~~ | ~~Winter 2025, low WUNI generation with HVDC North flow.~~ ~~Winter 2027, NI Dry condition~~ | ~~EDG-KAW 1-2 Overload Protection Scheme operates.~~ | Edgecumbe-Kawerau 110kV split means no power flows between EDG and KAW 110 kV circuits. Contingency is not valid anymore. |
| New contingencies tested: EDG T5 transformer | No violations | All scenarios checked | None | |
| Contingency assessed: KAW T12 or T13 220/110 kV interconnecting transformer | No violations | All scenarios checked | None | |
| KMO T2 or T4 220/110 kV Interconnecting transformer | Overload of the remaining KMO 220/110 kV interconnecting transformer. | Winter 2025, high loads at TGA, TMI, KMO and MTM during Low WUNI generation with HVDC North flow. Winter 2025 onwards, NI Dry condition scenarios. | Increase Kaimai or 110kV generation in GZ04 during peak. Otherwise, especially dry hydro scenarios, apply load management at GXPs in TGA,TMI,KMO,MTM and TMI. | KMO ICTs are considered as ECE[6] with no issues found. This requires a review of the event classification. GO is looking for SPS option to manage TGA Load in near future. |

[6] *Under N-1 conditions, HAM T6 and T9 have ECE event classification, as per the Credible Event Review 2024. (https://www.transpower.co.nz/system-operator/information-industry/operational-information-system/event-categorisation ).*

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| KMO-TGA-1 110 kV circuit | Overload of KMO-MTM-TGA-2 110 kV circuit. | High loads at TGA and MTM- Winter 2027. | Stage 1 of the KMO Intertrip scheme operates. | |
| MTI-WKM 1 or 2 220 kV circuits | Overload of the remaining MTI-WKM 220 kV circuit. | High MTI and WPA generation - Winter 2025 and 2027, Summer 2026. | MTI Runback scheme operates. | |
| KAW-MAT 1 or 2 110 kV circuits | Overload of the remaining KAW-MAT 110 kV circuit. | High Matahina and Aniwhenua generation – Summer peak loads All years. | Transfer limit based on KAW-MAT 1 or 2 VLR. | |

# 9 Grid Zone 5

## 9.1 Network overview

Grid Zone 5 covers the Hawke's Bay region. The region connects to Grid Zone 4 via 220 kV circuits from Wairakei and Grid Zone 7 via two 110 kV circuits from Waipawa. The 110 kV circuits are normally open at Waipawa. There are two 220/110 kV interconnecting transformers at Redclyffe providing power to the Hawke's Bay 110 kV network.

Major generators in the region include Whirinaki (WHI), Waikaremoana hydro scheme (WKA) and Harapaki wind farm.

The Hawke's Bay region is shown geographically and as a single line diagram in Figure 9-1 and Figure 9-2.

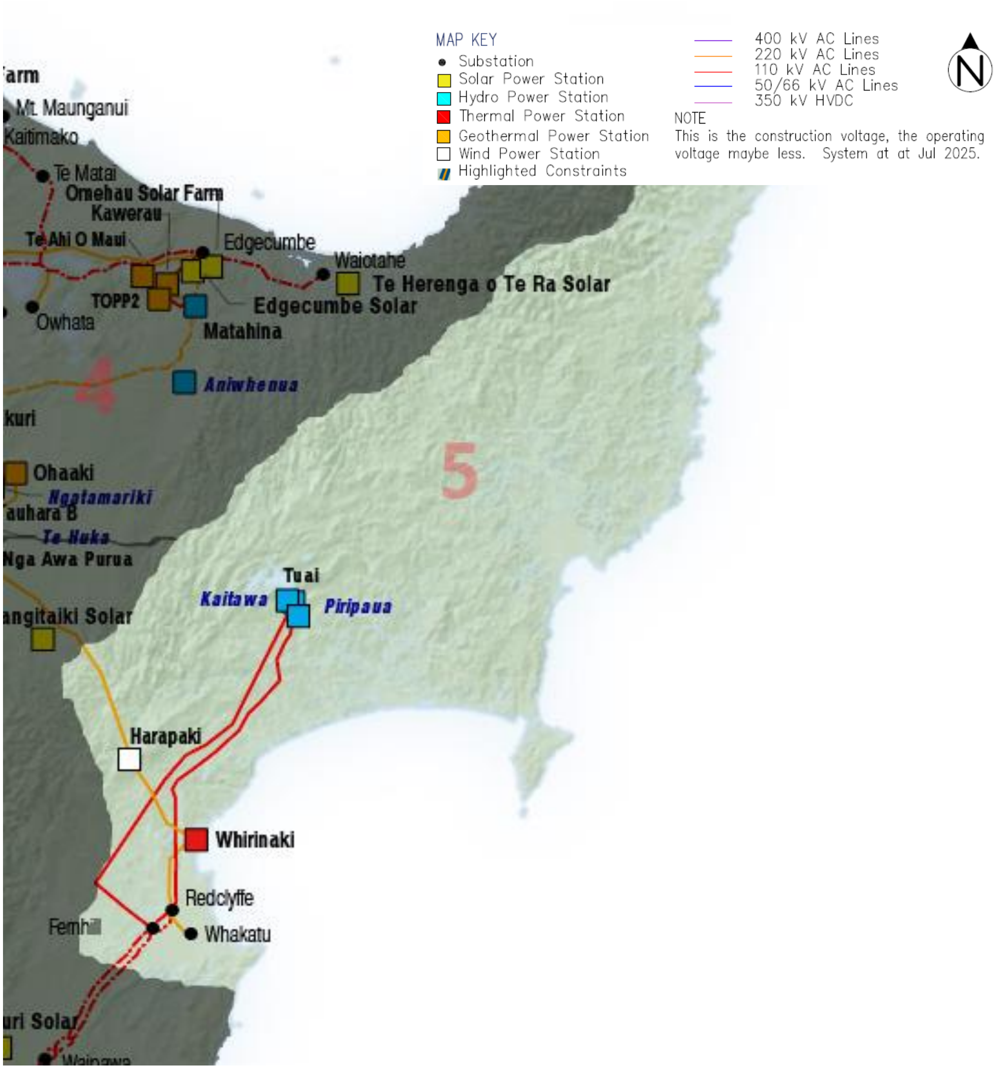


Figure 9-1: Geographic representation of Grid Zone 5

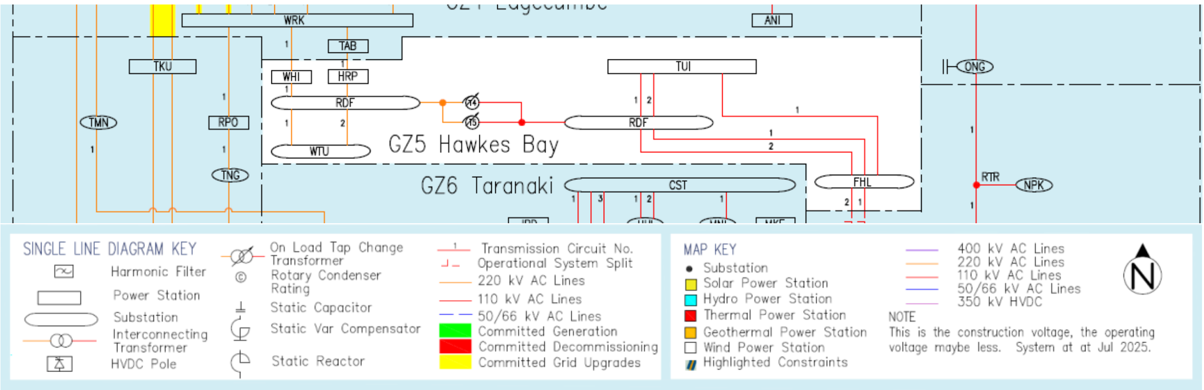


Figure 9-2: Single line diagram of Grid Zone 5

## 9.2 Committed projects and upgrades

The committed upgrades and generation in the Grid Zone over the period of study are shown in Table 9-1 and

Table 9-2 respectively.

Table 9-1: Summary of committed upgrades

| Asset | Changes | Commissioning Date |
|---|---|---|
| Redclyffe Interconnecting Transformer | Install third Redclyffe Interconnecting Transformer (RDF T5). | Commissioned |

Table 9-2: Summary of committed generation

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|---|
| Tuai (Genesis) | Hawke's Bay | Hydro | 68 (uprating) | Tuai | Commissioned |

## 9.3 Assumptions and background

The following assumptions were made for Grid Zone 5 studies, unless otherwise specified.

- A permanent system split is applied at FHL-WPA circuits, which is moved only when Waipawa is supplied from Fernhill rather than Dannevirke.
- RDF T3 T4 Transformer Protection Scheme is available, and normally enabled.
- NS1, NS2 and NS6 were studied.
- Specific to Grid Zone 5, the following cases were also studied for the contingency analysis:
  - High/Low WKA scheme generation, and
  - Low/High GZ5 wind
  - High WHI generation was studied in NS6 for the dry winter condition in the North Island. Otherwise WHI generation was dispatched low/off in NS1 and NS2.

- For voltage stability, the following cases were studied:
    - High/Low WKA scheme generation, and
    - Low/High WHI generation

## 9.4 Contingencies under intact network conditions (N-1)

Table 9-3 shows the circuits/transformers that would cause network violations within Grid Zone 5 if they tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 9-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| FHL-RDF-1 or 2 110 kV circuit | Overload of the remaining FHL-RDF 110 kV circuit. | All seasons, low Waikaremoana Generation, high load . | Implement security constraint to increase WKA output.<br>If WKA increase is not possible, limit load pre-contingency to < 56 MW/62 MW (summer/winter). | Limiting factor for distribution load transfer to WTU is the 100 MVA transformer, note WTU 220 kV bus is split and losing RDF_WTU_1 or RDF_WTU_2 will cause WTU T3 or T4 to overload (No CB on either side of the 220 kV bus at WTU). |
| RDF 220/110 kV T3 or T4 interconnecting transformer | Overload of the remaining RDF 220/110 kV interconnecting Transformer. | Low Waikaremoana Generation, high Grid Zone 5 load. | Enable RDF T3 T4 Transformer Protection Scheme. | Overloading on the remaining RDF transformer is resolved with SPS enabled. The installation of the 3rd RDF transformer ~~in July 2025~~ will resolve the issue. |

## 9.5 Voltage stability studies

A voltage stability analysis was conducted on Grid Zone 5 where the voltage stability limit is determined by the maximum pre-contingency real power that can be transferred into the region. To reach the voltage stability limits, the pre-contingency real power growth needs to exceed at least 30% of the estimated winter load growth. Through this analysis, the most limiting contingency for Grid Zone 5 was identified as WHI-WRK-1 220kV. No voltage stability issues are expected for Grid Zone 5.

# 10 Grid Zone 6

## 10.1 Network overview

Grid Zone 6 comprises the Taranaki region which is bordered by and includes Brunswick in the east. It is supplied by 220 kV and 110 kV transmission circuits with 220/110 kV interconnecting transformers (ICTs) at Stratford.

The Taranaki region is shown geographically and as a single line diagram in Figure 10-1 and Figure 10-2.

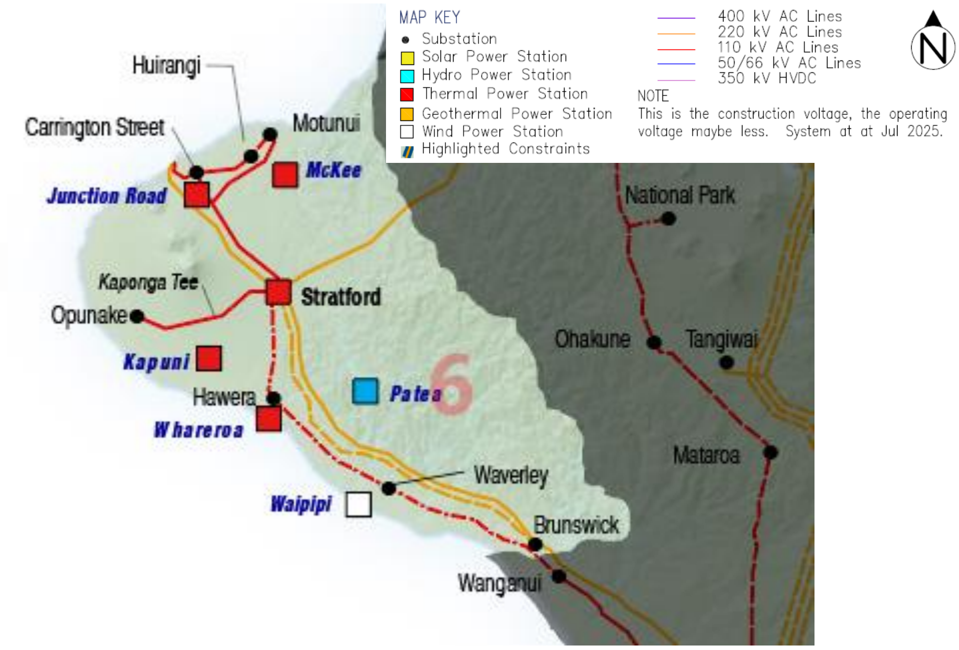


Figure 10-1: Geographic representation of Grid Zone 6

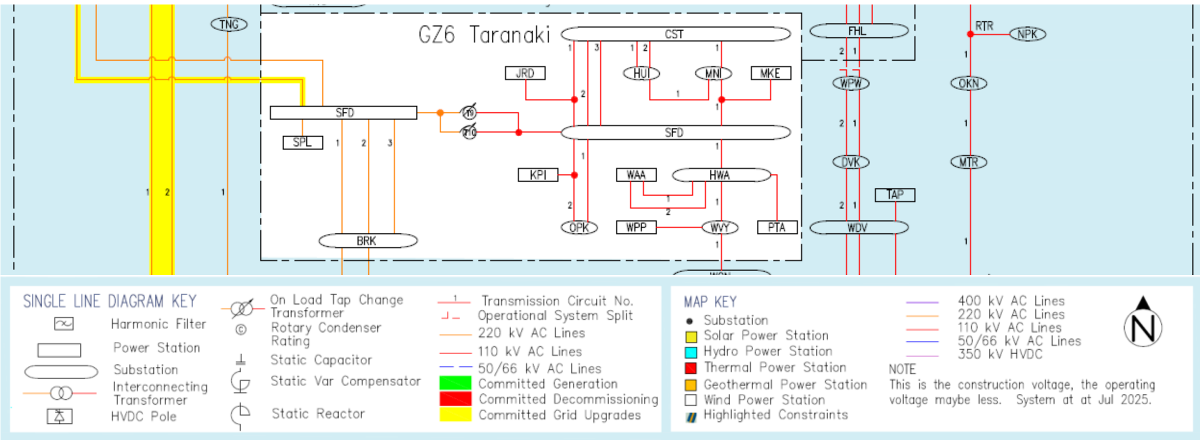


Figure 10-2: Single line diagram of Grid Zone 6

## 10.2 Committed projects and upgrades

The committed upgrade in the Grid Zone over the period of study is shown in Table 10-1.

Table 10-1: Summary of committed upgrade

| Asset | Changes | Commissioning Date |
|---|---|---|
| Huntly–Stratford 220 kV circuit | NZGP Stage 1 - Remove line protection static limit on the Huntly–Stratford circuit. | April-2026 |
| Brunswick Supply Transformer | Brunswick new supply transformer | December-2027 |
| Hawera Supply Transformers | Outdoor to indoor conversion project and protection upgrade project | Commissioned |

## 10.3 Assumptions and background

The following assumptions were made for Grid Zone 6 studies, unless otherwise specified:

- WGN Under-Voltage Load Shedding (UVLS) Scheme is operational, normally disabled.
- HWA Automatic Under-Voltage Load Shedding (AUVLS) Scheme is operational, normally disabled.
- MTN-WGN Circuit Overload Protection Scheme is operational, normally enabled.
- While Contact has not confirmed the closure of the Taranaki Combined Cycle (TCC) gas power plant, the sensitivity without TCC was studied in NS2.

The study scenarios shown in Table 10-2 were developed in order to determine security issues and transfer limits for Grid Zone 6.

Table 10-2: System conditions and applied sensitivities studied under Grid Zone 6.

| | System condition | Grid Zone 6 Demand | HVDC Transfer | 220 kV Grid Zone 6 Generation | 110 kV Grid Zone 6 Generation | NI wind generation[7] |
|---|---|---|---|---|---|---|
| 1 | NS1 | Winter Peak | High DC North (DCN) | High | High | High |
| 2 | NS1 | Winter Peak | High DC North | High | Low | High |
| 3 | NS2 | Summer Peak | High DC North | Low | High | High |
| 4 | NS2 | Summer Peak | High DC North | Low | Low | High |
| 5 | NS3 | Winter Peak | High DC South (DCS) | High | High | Low |
| 6 | NS3 | Winter Peak | High DC South | High | Low | Low |
| 7 | NS4 | Summer Peak | High DC South | High | High | Low |
| 8 | NS4 | Summer Peak | High DC South | High | Low | Low |
| 9 | NS6 | Winter Peak | High DC South | High | High | Med |

[7] *High > 75% wind generation, Low < 30% wind generation, Med = 50% wind generation*

| | System condition | Grid Zone 6 Demand | HVDC Transfer | 220 kV Grid Zone 6 Generation | 110 kV Grid Zone 6 Generation | NI wind generation[7] |
|---|---|---|---|---|---|---|
| 10 | NS6 | Winter Peak | High DC South | High | Low | Med |

Where necessary, minor deviations were made to the above scenarios for each grid configuration considered in these studies to arrive at the worst-case security violations and transfer limits.

## 10.4 Contingencies under intact network conditions (N-1)

Table 10-3 shows the circuits/transformers that would cause network violations within Grid Zone 6 if they tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 10-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| SFD T9 220/110 kV interconnecting transformer | Overload of SFD T10 220/110 kV interconnecting transformer. | Summer, high DC south transfer, low wind, low 110 kV Grid Zone 6 generation. | None[8] | 1. SFD-TF-T9 rated 200/200 MVA (HV/MV), SFD-TF-T10 rated 116/100 MVA (HV/MV). When SFD is transformers are loaded above 100 MVA and SFD-TF-9 trips, there is a possibility to overload T10.<br>2. If T10 trips on overload, there will be possible voltage stability issues in Grid Zone 6 as load will in Grid Zone 6 will be fed via HWA-SFD circuit.<br>3. HWA AUVLS scheme operates to shed load at HWA (Normally disabled). Other than specified planned outages, the HWA AUVLS scheme needs to be enabled at any time where low post-contingent voltages will be apparent at HWA. |

[8] *Credible Event Review - Scope 2024 document classifies SFD 220/110 T10 as other, hence there is no pre-contingency measures will be applied.*

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| HWA-SFD-1 110 kV circuit | Overload of BPE-MTN-1 and 2 sections of the BPE-WGN- 1 and 2 110 kV circuits, low voltages at Pātea, Hāwera, Waverley and Whareroa. | All seasons and years, low 110 kV Grid Zone 6 generation. | HWA AUVLS scheme needs to be enabled for low generation on the HWA-WGN-WVY circuit (WPP, WAA, PTA). | 1. If WPP is synchronized, V-control from the generating station will support the voltage at WVY. 2. Loss of HWA-SFD causes HWA-WGN-WVY circuit to be fed radially from BPE. At peak loads for summer/winter and lack of generation at the end of the radial network, voltages drop with the lines potentially overloading. Mitigation: HWA AUVLS scheme to shed load at HWA. Hence HWA AUVLS scheme needs to be enabled for low generation on the HWA-WGN-WVY circuit (WPP, WAA, PTA). |
| BRK-SFD-1 or 2 220 kV circuit | Overload of the remaining BRK-SFD 220 kV circuits. | Summer, high DC transfer south, low wind, high 110 kV Grid Zone 6 generation. | Market/SO Tools to limit the DCS transfer to mitigate overloading for BRK-SFD. | |
| TCC | Overload of BPE-TNG-1 and RPO-TNG-1 220 kV circuits. | Winter, high DC transfer south, low wind, high or low 110 kV Grid Zone 6 generation. | Market/SO tools to limit the DCS transfer to mitigate overloading. | |

# 11 Grid Zone 7

## 11.1 Network overview

Grid Zone 7 comprises the Bunnythorpe region and it is bordered by and includes Mangahao in the south and Ongarue in the north. This zone is supplied by 220 kV and 110 kV transmission circuits with two 220/110 kV interconnecting transformers at Bunnythorpe. During normal operations Waipawa to Fernhill 110 kV circuits are open.

The Bunnythorpe region is shown geographically and as a single line diagram in Figure 11-1 and Figure 11-2.

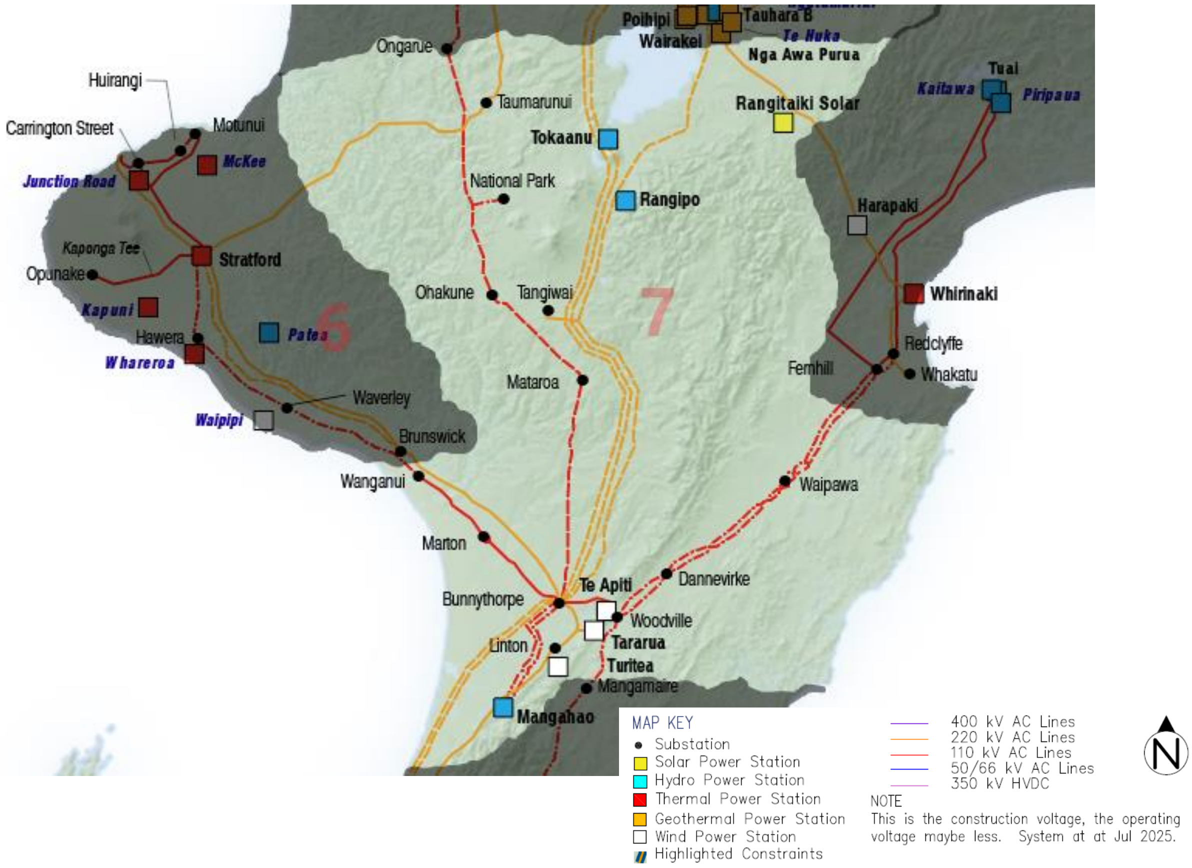


Figure 11-1: Geographic representation of Grid Zone 7

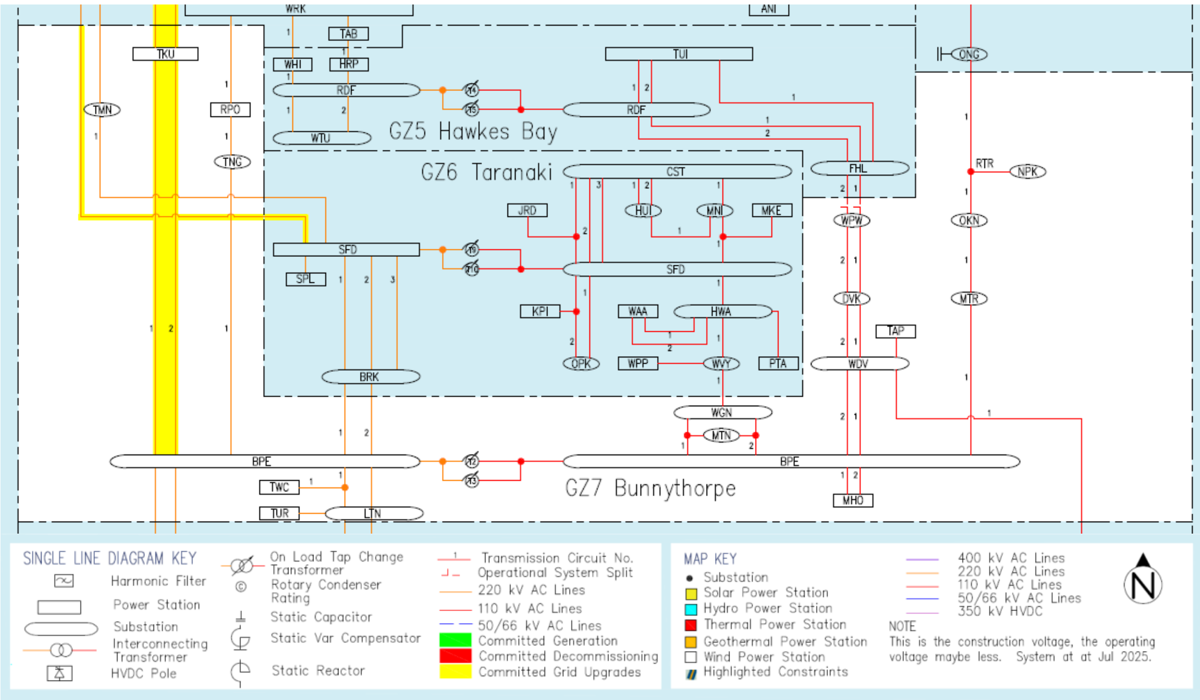


Figure 11-2: Single line diagram of Grid Zone 7

## 11.2 Committed projects and upgrades

The committed upgrades in the Grid Zone over the period of study are shown in Table 11-1.

Table 11-1: Summary of committed upgrade

| Asset | Changes | Commissioning Date |
|---|---|---|
| Marton Supply Transformers | Outdoor to indoor conversion project and protection upgrade project (removes the protection constraint). | July-2026 |
| Bunnythorpe–Ongarue 110 kV system | NZGP Stage 1 - Ongarue 110 kV split. | April-2026 |
| Bunnythorpe–Tokaanu circuits | NZGP Stage 1 - Thermally upgrade the Bunnythorpe–Tokaanu circuits and implement variable line ratings. | April-2029 |

## 11.3 Assumptions and background

The following assumptions were made for Grid Zone 7 studies:

- HVDC injection/load is at Haywards 220 kV bus.
- TKU Circuit Overload Protection Scheme is available, normally enabled.
- BPE-WDV 1 and 2 Circuit Overload Protection Scheme is available, normally enabled.
- BPE-MTR Circuit Overload Protection Scheme are available, normally enabled.

- Fernhill-Waipawa 1 and 2 110 kV circuits are normally open.
- Summer and winter peak load scenarios were studied for all outages with maximum and minimum wind generation for both north and south HVDC transfers.
- Constraints on HVDC north flow scenarios were studied with maximum wind generation. Some constraints for N-1 conditions only bound in winter with high HVDC and maximum wind generation.
- The following scenarios have been studied which mainly based on the North Island backbone system conditions including particular sensitivities that applies to Grid Zone 7:
    - NS1 - HVDC North Flow Low HLY at Winter Peak (including sensitivities with high hydro generation, and 80% wind).
    - NS2 – HVDC North Flow Low HLY (including sensitivities with low hydro generation, and 80% wind).
    - NS3 – HVDC South Flow – Winter Peak.
    - NS4 - HVDC South Flow – Summer Peak.

### 11.3.1 Steady state violations

Table 11-2 shows the network violations within Grid Zone 7, that occur during steady state network conditions with all circuits in service. Table 11-2 also outlines the operational measures likely to be taken during these violations.

Table 11-2: Summary of steady state violations

| Effect on System | Scenario | Operational Measure |
|---|---|---|
| Overload of BPE-MTR-1 110 kV circuit in steady state conditions. | HVDC high north flow, low Huntly generation, high wind, winter 2025. | SPD will adjust generation dispatch to maintain the loading within the branch limits. |

## 11.4 Contingencies under intact network conditions (N-1)

Table 11-3 shows the circuits/transformers that would cause network violations within Grid Zone 7 if tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 11-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| SFD-TMN-1, TMN-TWH-1 220 kV circuits | Overload of BPE-MTR-1 110 kV circuit. | HVDC high north flow Winter 2025- High wind. | BPE-MTR Circuit Overload Protection Scheme operates. | - |
| TKU-WKM-1 or 2 220 kV circuit | Overload of the remaining TKU-WKM 220 kV circuit. After operation of TKU Circuit Overload Protection Scheme BPE-MTR-1 110 kV circuit Overloads. | HVDC high north flow High wind. High TKU generation Winter 2025 | TKU Circuit Overload Protection Scheme operates then BPE-MTR Circuit Overload Protection Scheme operates. | See notes below |

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| | After operation of the BPE-MTR Circuit Overload Protection Scheme, remaining TKU-WKM 220 kV circuit overloads again. | | Limit power transfer northwards during high wind using thermal constraints. | |
| RPO-WRK-1 220 kV circuit | Overload of BPE-MTR-1 110 kV circuit. | HVDC high north flow, low HLY, high wind, high TKU generation, high RPO generation, Winter 2025. | BPE-MTR Circuit Overload Protection Scheme operates. | - |
| BPE-TKU-1 220 kV circuit or TCC | Overload of RPO-TNG-1 220 kV circuit. | HVDC south flow, High RPO generation, Winter 2027. | Limit power transfer southwards using thermal constraints. | - |
| BPE-WDV-1 or 2 110 kV circuit | Overload of the remaining BPE-WDV 110 kV circuit. | HVDC south flow, Summer/Winter, all years. | BPE-WDV Circuit Overload Protection Scheme operates. | - |

### 11.4.1 Loss of Tokaanu-Whakamaru-1 or 2 220 kV circuit:

Tokaanu-Whakamaru-1 or 2 220 kV circuits are the worst N-1 contingencies for HVDC north transfer with high Tokaanu and wind generation. Tokaanu Circuit Overload Protection Scheme will be operated following the tripping of Tokaanu-Whakamaru-1 or 2 220 kV circuit, leading to an overload of the Bunnythorpe-Mataroa-1 110 kV circuit. This causes the operation of Bunnythorpe-Mataroa Circuit Overload Protection Scheme, which will eventually overload the remaining Tokaanu-Whakamaru 220 kV circuit again with high Tokaanu generation.

# 12 Grid Zone 8

## 12.1 Network overview

Grid Zone 8 comprises the Wellington region, which is bordered by and includes Mangamaire and Paraparaumu in the north. It is supplied over 220 kV and 110 kV transmission circuits with interconnecting transformers at Haywards and Wilton. The HVDC link, static capacitors, a STATCOM and synchronous condensers are installed at the Haywards substation. There is wind generation at West Wind and Mill Creek.

The Wellington region is shown geographically and as a single line diagram in Figure 12-1 and Figure 12-2.

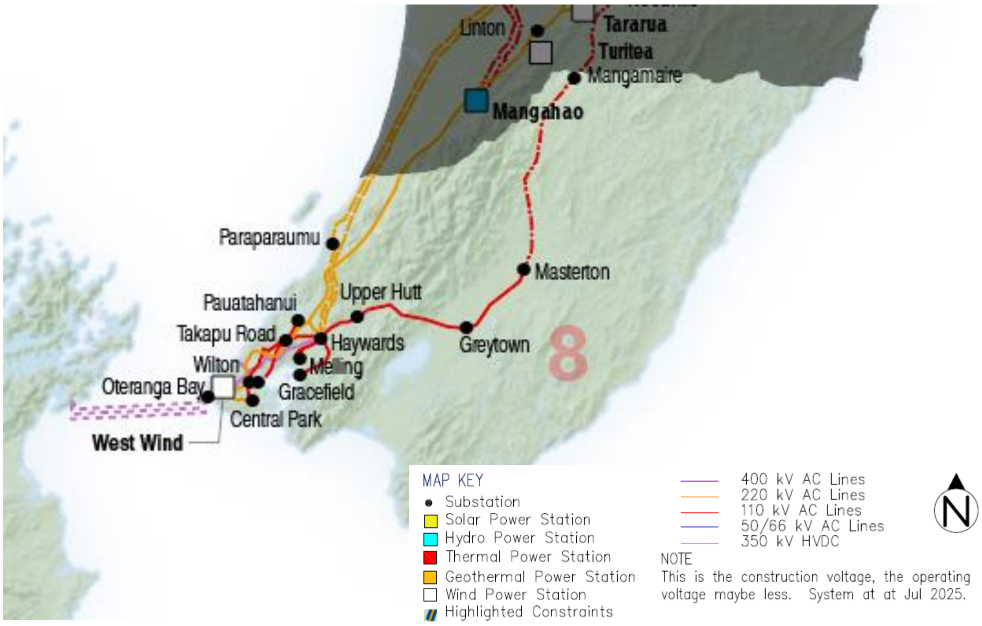


Figure 12-1: Geographic representation of Grid Zone 8

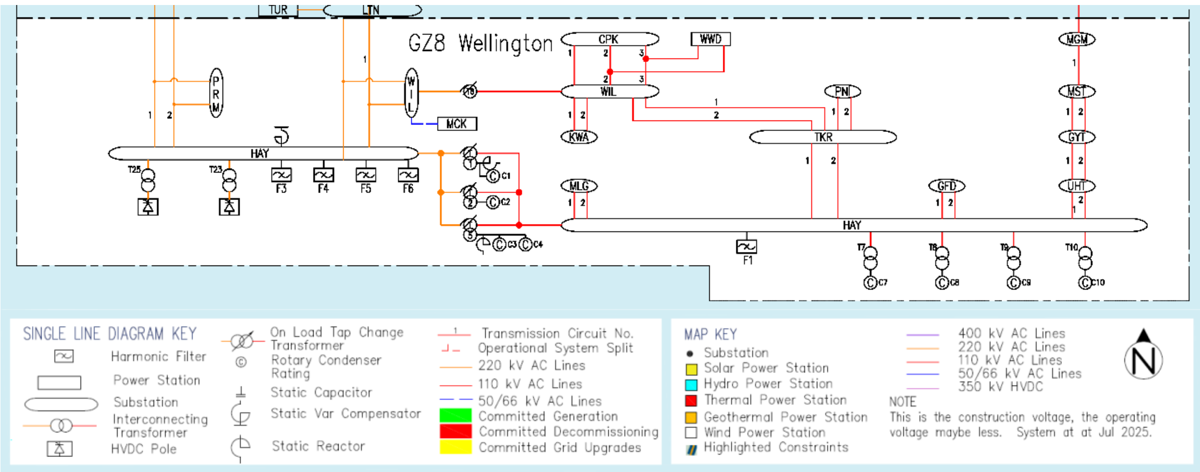


Figure 12-2: Single line diagram of Grid Zone 8

## 12.2 Committed projects and upgrades

There are no committed upgrades in this Grid Zone over the period of this study.

## 12.3 Assumptions and background

The following assumptions and background information were considered for Grid Zone 8 studies unless specified otherwise in the detailed analysis.

- MGM Overload Trip and Autochangeover scheme is available, normally disabled.
- CPK Transformer Overload Protection Scheme is available, normally disabled.
- Both HVDC poles are available and in service.
- All the reactive devices managed by the HVDC control system are available and switched based on preferred filter requirements with bipole operation.
- The following scenarios have been studied:
  - NS1 - HVDC North Flow Low HLY at Winter Peak (including high hydro generation and high wind).
  - NS2 – HVDC North Flow Low HLY (including low hydro generation, but no wind or solar sensitivity).
  - NS3 - HVDC South Flow – Winter Peak
  - NS4 - HVDC South Flow – Summer Peak
  - NS5 – Summer Trough load (including high solar and low wind)
- While Contact has not confirmed the closure of the TCC gas power plant, its unavailability was studied for voltage stability and its potential impact on 220 kV circuit loadings during high HVDC south transfer. Without TCC, the HVDC south transfer is mainly limited by the 220 kV circuits from the central North Island during high Wellington load and low wind generation near Haywards. To maintain the HVDC south transfer, all "minimum wind" scenarios had TCC assumed to be running (TCC in) while for "maximum wind" scenarios TCC was out of service (TCC out).

### 12.3.1 HVDC capability

The maximum HVDC transfer capability is shown in Table 12-1 at a power factor of 0.9. All reactive power units at Haywards must be available to facilitate these transfer capabilities.

Table 12-1: Maximum HVDC transfer capability

| HVDC Transfer | MW (sent) | MW (received) |
|---|---|---|
| North transfer | 1200 | 1132 |
| South transfer | 850 | 816 |

The installed capacity of generation in the North Island is now approximately 6,678 MW, including 1,100 MW of wind generation. The forecast North Island winter peak load in 2027 is approximately 5,850 MW, excluding system losses.

In this study, the minimum-wind to maximum-wind generation range for all the wind generators included in this study is from 219 MW to 986 MW. During the periods characterised by high loads and southward HVDC flow, scenarios where wind generation drops to 0% risk insufficient generation to meet North Island load requirements. To account for varying concurrent peak and trough wind contributions across Wellington and Wairarapa regions, the range of wind generation was chosen.

#### *12.3.1.1 HVDC power limits and runbacks at Haywards*

The HVDC control system automatically applies a lower maximum transfer capability limit (known as a power limit) during network outages and certain other network conditions. The calculation of the power limits is quite complex. It is summarized below for Haywards, with a description of the potential effect on the north and south transfer constraints related to the HVDC link.

The automatic limiting action is applied across all load conditions but for different conditions. For example, under low load conditions in Grid zone 8 during outages, the maximum transfer is limited in both directions. This limitation is to avoid overvoltage if the bipole power transfer is interrupted with all AC harmonic filters in service. In addition to a bipole trip, a bipole power interruption can occur for an AC network fault at the other end of the HVDC link. Another example is under high load conditions with or without outages, where the maximum south flow transfer is limited to ensure sufficient reactive power margin at Haywards to maintain voltage control.

The control system uses a range of real-time data inputs to determine a limit. For Haywards this includes:

- The DC transfer capability in the appropriate power direction;
- An estimate of the Grid Zone 8 load, the status of all the 220 kV transmission circuits north of Bunnythorpe to Haywards;
- The status of Haywards interconnectors, Haywards busbar voltage and bus configuration; and
- The status and reactive power output of all the reactive power plant at Haywards (i.e. the AC harmonic filters, condensers, and the STATCOM).

The Grid Zone 8 load is measured as this is a significant factor for how much the maximum HVDC transfer needs to be limited. To do this the HVDC control system does not measure the Grid Zone 8 load directly, instead it uses the measurement of power flowing in the Haywards and Wilton 220/110 kV interconnecting transformers plus a measure of the load at Paraparaumu 33 kV substation to approximate this. Of the lower North Island wind generation, only West Wind is within this measurement boundary. Mill Creek connects to the 220 kV at Wilton Substation via the 33 kV so is outside this measurement boundary.

### 12.3.1.2 HVDC north flow limits with an intact network

The Grid Zone 8 load net of West Wind output is a good approximation to the value that the HVDC control system will be using during north flow conditions on the HVDC link as shown in Table 12-2.

Table 12-2: HVDC transfer and Grid Zone 8 load – North flow scenario

| Year | HVDC north flow (MW) | Grid Zone 8 demand (MW) | HVDC load measurement (1): minimum wind (MW) | HVDC load measurement: maximum wind (MW) |
|---|---|---|---|---|
| 2024 Summer Peak | 1200 | 472 | 441 | 328 |
| 2025 Winter Peak | 1200 | 730 | 676 | 561 |
| 2026 Summer Peak | 1200 | 505 | 479 | 375 |
| 2027 Winter Peak | 1200 | 757 | 727 | 599 |

### 12.3.1.3 HVDC north flow limits for AC circuit outages

During north flow the maximum reduction to the HVDC north flow limit, due to a 220 kV circuit outage, is applied for load measured below 250 MW[9]. The reduction to HVDC north flow limit decreases linearly to zero for loads between 250 and 500 MW[10]. For each 220 kV circuit outage between Bunnythorpe and Haywards the maximum reduction is 150 MW[11], and for the Haywards to Wilton 220 kV circuit the maximum reduction is 100 MW. An example is shown below in Table 12-3.

Table 12-3: HVDC transfer limits example – North flow outage scenario

| Outage Scenario | HVDC load measurement (MW) | HVDC north transfer power limit (MW) |
|---|---|---|
| 220 kV circuit out of service between Bunnythorpe and Haywards (except Haywards to Wilton 220 kV circuit), all other circuits in service and reactive power equipment available. | <= 250 | 1050 |
| | 375 | 1125 |
| | >= 500 | 1200 |

The HVDC north transfer power limit may remove the need for constraint equations to be applied during N-1 and N-1-1 outage conditions, especially for low load and high wind output conditions.

### 12.3.1.4 HVDC south flow limits with an intact network

For south flow, the HVDC control system applies a power limit of 850 MW for load measurements up to 400 MW. This then reduces with a slope of 1.383 MW/MW for loads above 400 MW. When power is flowing south into the Wellington area from Mangamaire on the Mangamaire-Masterton 1 110 kV circuit, the HVDC load measurement will be lower than the actual Grid Zone 8 load. This is due to a combination of West Wind and south power transfer on the Mangamaire-Masterton 1 110 kV circuit,

[9] HVDC load measurement is the combined MW value measured at Haywards and Wilton 220/110 kV interconnecting transformers plus the load measured at Paraparaumu 33 kV substation.
[10] *For further information see the [HVDC Bipole Operating Policy]*
[11] *Circuits that are in series are not double counted.*

reducing the net load seen by the Grid Zone 8 interconnecting transformers. The indicative maximum HVDC south flow for the peak demand conditions in these studies is shown below in Table 12-4.

Table 12-4: HVDC transfer and Grid Zone 8 load – South flow scenario

| Year | Grid Zone 8 demand (MW) | HVDC load measurement (MW) | HVDC south flow power limit (MW) |
|---|---|---|---|
| 2024 Summer Peak (minimum wind) | 472 | 382 | 850 |
| 2024 Summer Peak (maximum wind) | 472 | 281 | 850 |
| 2025 Winter Peak (minimum wind) | 730 | 613 | 556 |
| 2025 Winter Peak (maximum wind) | 730 | 514 | 693 |
| 2026 Summer Peak (minimum wind) | 505 | 414 | 830 |
| 2026 Summer Peak (maximum wind) | 505 | 312 | 850 |
| 2027 Winter Peak (minimum wind) | 757 | 619 | 548 |
| 2027 Winter Peak (maximum wind) | 757 | 539 | 657 |

#### *12.3.1.5 HVDC south flow limits for AC circuit outages*

Outages reduce the HVDC south flow limit further. For south transfer at times of low system load there is an HVDC control system calculated limitation to limit over-voltages, similar to the north flow case. However, for south transfer at high system load there is a second limit calculated for outages to ensure the reactive power margin is retained. This second limit applies a maximum reduction at loads above 500 MW, reducing linearly to zero for loads below 250 MW. For south flow at high load, the maximum reduction is 100 MW for the first 220 kV circuit outage, and 150 MW for each subsequent 220 kV circuit outage. The final south flow limit is the lowest of the calculated limits. As outages have their maximum effect on the power limit at both low and high system demand, the best possible south transfer during outages is often for medium system demand periods.

The HVDC south transfer power limit assumes favourable operating conditions and high generation from all lower North Island windfarms to avoid the introduction of constraints. The power limits are therefore unlikely to be achieved on the network under normal operation and it is likely that constraint equations will be applied, resulting in lower transfer limits than those permissible by the HVDC control system.

#### *12.3.1.6 HVDC runbacks*

The HVDC control system can also apply an automatic reduction to its MW transfer level (known as a runback) under certain conditions, even if the transfer level is below the maximum power limit. This runback is a single reduction of 100 MW in the dispatched power level which is applied as a slow ramp (100 MW/minute). For Haywards, two conditions that could trigger a runback are if the 220 kV bus voltage is below 209 kV for 5 seconds, or if there is less than 80 Mvar of reactive power margin for 30 seconds. These runbacks are intended to ensure that even with unusual operating circumstances the HVDC power transfer does not create a voltage stability issue. These runbacks do not over-ride the frequency keeping control (FKC), and because this is the normal operation of the HVDC link, both the voltage and reactive power conditions noted above are avoided using manual constraints.

### 12.3.2 Steady state violations

Table 12-5 shows the circuit that would cause network violations within Grid Zone 8 if the system condition matches the described scenario outlined. It also outlines the operational measures likely to be taken to mitigate the effect of this violation.

Table 12-5: Summary of steady state violations

| Effect on system | Scenario | Operational Measure |
|---|---|---|
| Overload of RPO-TNG-1 220 kV circuit in steady state conditions. | Peak demand, high south HVDC flow, All years and seasons. TCC in and out of service | Generation north of RPO-TNG-1 will be constrained using branch constraints to manage pre-contingent south flows. |

## 12.4 Contingencies under intact network conditions (N-1)

Table 12-6 shows the circuits/transformers that would cause network violations within Grid Zone 8 if they tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 12-6: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure |
|---|---|---|---|
| MGM-MST-1 110 kV circuit | Over voltage issue at Mangamaire. | 2024, low loads during maximum wind scenario. | Assuming TAP is online, V-control from the generating station will support the voltage at MGM/WDV. The interconnecting transformers at BPE can be tapped to reduce MVAR flow into the 110 kV network north of BPE. |
| MGM-WDV-1 110 kV circuit | Over voltage issue at Woodville. | Winter 2025, peak loads during maximum wind scenario. | |
| HAY-WIL-LTN-1 or 2 220 kV circuits | Insufficient reactive power margin at HAY that could possibly trigger the HVDC runback scheme described in 10.2. | Winter all year, peak Grid Zone 8 loads. | This would require a pre-contingent reactive power margin greater than 200MVAR, however as Grid Zone 8 loads increase, this may not be possible. |
| HAY-WIL-LTN-1 or 2 220 kV circuits | Overload or BPE-WDV-1 and 2 110 kV circuits | Winter 2025, minimum wind. | A system split on MGM-MST-1 110 kV circuit will alleviate this issue. |

## 12.5 Voltage stability studies

### 12.5.1 Definitions

The voltage stability limit for the Grid Zone 8 is defined as the maximum pre-contingency real power that can be transferred into the region to avoid voltage collapse after the loss of a key power system component.

The amount of real power transferred into the region is defined as the sum of real power flowing on the 220 kV and 110 kV circuits into the region, namely:

- Bunnythorpe Paraparaumu Haywards 1 and 2 220 kV circuits
- Haywards Wilton Linton 1 and 2 220 kV circuits
- Mangamaire Woodville-1 110 kV circuit

Voltage Stability Transfer Limit (MW) is the pre-contingent transfer limit on the circuits into Grid Zone 8 before voltage collapse.

HVDC load measurement (MW) - HVDC load measurement is the combined MW value measured at Haywards and Wilton 220/110 kV interconnecting transformers plus the load measured at Paraparaumu 33 kV substation.

HVDC transfer limit (MW)- is an automatic limit on the absolute maximum HVDC transfer, specified as the value at Haywards. For a north flow scenario, it is the MW figure received at Haywards, and south flow is the MW figure sent from Haywards. Some key voltage stability terms used in this study are defined below.

- Thermal Transfer Limit (MW) is the pre-contingent transfer limit on the circuits into the Grid Zone 8 with all transmission circuits loaded within rated capability.
- Thermal HVDC load measurement (MW) is the HVDC load measurement, as defined above, but measured when the Thermal Transfer limit has been reached.
- Thermal HVDC transfer limit (MW) is an automatic limit on the absolute maximum HVDC transfer, specified as the value at Haywards. This limit occurs when the Thermal Transfer Limit (MW) is reached.

The following permanent voltage stability constraint has been published to the market to indicate the voltage stability limit in Grid Zone 8:

| | |
|---|---|
| Constraint Name: | WELLINGTON_STABILITY_P_1D |
| Constraint Equation: | 1*BPE_PRM_HAY1.1 + 1*BPE_PRM_HAY2.1 - 1*HAY_WIL_LTN1.1 - 1*HAY_WIL_LTN2.1 - 1*MGM_WDV1.1<= Limit |

The transfer limit and constraint equations are only indicative, as actual limits and constraint equations will depend on real-time system conditions.

Apart from voltage stability studies for an intact grid, multiple boundary circuits into Grid Zone 8 were examined as contingencies. The objective is to ascertain voltage stability parameters, HVDC load measurements, and HVDC transfer limits for southward flow for the most limiting contingency. This is reported below.

### 12.5.2 Loss of a Haywards-Wilton-Linton 220 kV circuit

The voltage stability of Grid Zone 8 for this contingency was studied for all years, all seasons, in maximum and minimum wind scenarios with TCC sensitivity with HVDC south transfer. Apart from the summer peak load in 2024 and winter peak loads in 2025 and 2027, as reported in Table 12-7 below, the voltage stability load limits were above the load forecast with adequate margin for the rest of the study cases.

The voltage stability transfer limits in Table 12-7 show the indicative limit for the permanent voltage stability constraint equation stated above that would be applicable for the scenarios studied. In real-time operations the limit is determined more accurately using online voltage stability analysis tools.

Table 12-7: Voltage stability limits for a loss of Haywards-Wilton-Linton 220 kV circuit

| Year | Scenario | Voltage Stability Transfer Limit (MW) | HVDC load measurement (MW) | HVDC transfer limit (MW) | Thermal Transfer limit (MW) | Thermal HVDC load measurement (MW) | Thermal HVDC transfer limit (MW) |
|---|---|---|---|---|---|---|---|
| 2024 Summer | Minimum Wind - TCC in | 932 | 371 | 850 | 790 | 381 | 850 |
| 2025 Winter | Minimum Wind -TCC in | 992 | 613 | 556 | 836 | 600 | 574 |
| 2025 Winter | Minimum Wind -TCC out | 902 | 620 | 546 | 897 | 620 | 545 |
| 2027 Winter | Minimum Wind -TCC in | 1012 | 637 | 522 | 945 | 618 | 548 |
| 2027 Winter | Maximum Wind -TCC out | 1179 | 532 | 667 | NA | NA | NA |

During high HVDC south flow, the loss of one of the Haywards-Wilton-Linton 1 or 2 220 kV circuits may result in voltage collapse in the lower North Island if this is not managed. For the cases reported, Bunnythorpe-Woodville circuits 1 and 2 reaches their thermal limit before the voltage stability limit is reached. Hence the thermal transfer limit is reported as the limiting factor for the zone.

A minimum wind scenario was studied with TCC modelled out of service to determine its potential impact on HVDC south transfer. Regardless of TCC's status, generation north of Bunnythorpe will still need to be constrained to avoid overloading the circuits into Grid Zone 8. Due to the HVDC load measurement values and the minimum wind used in the study, the HVDC transfer limits remain above 500 MW with TCC out of service. However, if the wind contribution decreases below the studied minimum or the zone load increases, this limit will decrease.

The maximum HVDC south flow that can be accommodated in these cases depends on HVDC load measurement, Grid Zone 8 wind farm output and reactive plant availability at Haywards.

# 13 Grid Zone 9

## 13.1 Network overview

Grid Zone 9 covers the Nelson-Marlborough region, which is the top of the South Island. Power is predominantly supplied to the region through three 220 kV circuits from the Islington substation. There are interconnecting transformers at Kikiwa[12] and Stoke providing power to the Nelson-Marlborough 110 kV network.

Major generators in the region include the embedded generators at Cobb and Argyle (the Branch River Scheme). These local generators provide important voltage and load support to the region. In addition, a STATCOM is installed at Kikiwa, and a few static capacitors are installed at Stoke and Blenheim to support network voltage and voltage stability performance. A 110 kV reactor is also installed at Kikiwa for high voltage management during the light load periods.

The Nelson-Marlborough region is shown geographically and as a single line diagram in Figure 13-1 and Figure 13-2.

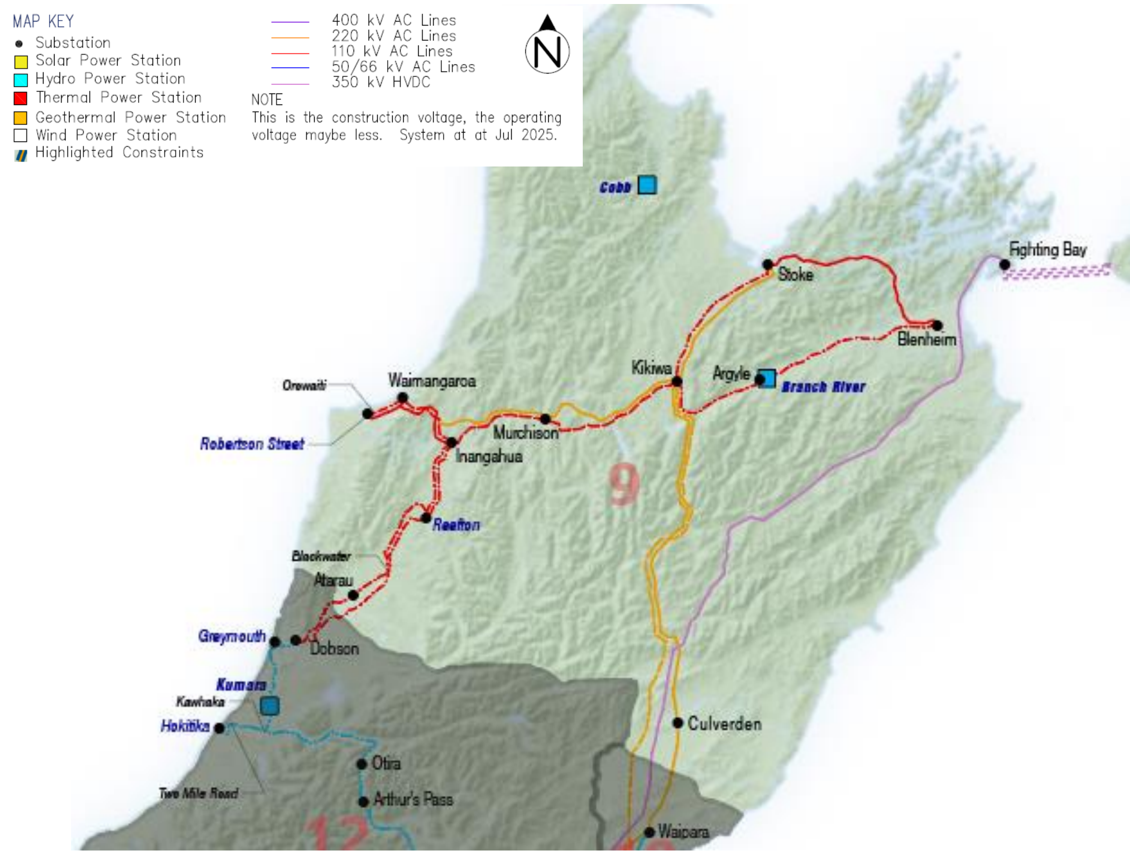


Figure 13-1: Geographic representation of Grid Zone 9

[12] There are two 220/110/11kV interconnecting transformers at Kikiwa (Kikiwa T1 and T2). Kikiwa T2, which is the larger interconnector, is normally in service to supply the Grid Zone 9 110 kV network. Kikiwa T1 is normally opened at the 110 kV side. Either T1 or T2 can supply the Kikiwa 11kV load.

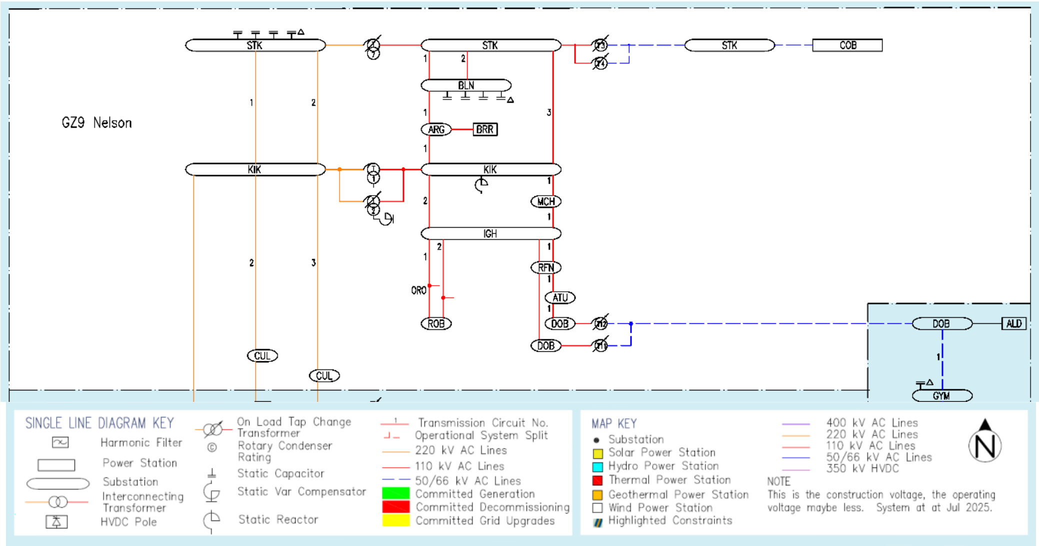


Figure 13-2: Single line diagram of Grid Zone 9

## 13.2 Committed projects and upgrades

There are no committed upgrades in Grid Zone 9 for the study period.

## 13.3 Assumptions and background

The following assumptions were made for Grid Zone 9 studies, unless specified otherwise in the detailed analysis:

- All reactive power devices in the region were assumed to be available for all study cases including Islington C15, which is due to return to service in July 2024. However, it was not necessary to switch in Islington C15 for any of the studied years or contingencies.
- Major generation assumed to be available for voltage support were:
  - Cobb (COB) generation
  - Argyle (ARG) generation
  - Coleridge (COL) generation
- BLN-KIK 110 kV Circuit Overload Protection Scheme is assumed to be operational and enabled as normal.
- The following study scenarios were developed to determine security issues and transfer limits for Grid Zone 9:
  - SS1 – Low USI generation with high winter demand as described in South Island Backbone study with Grid Zone 9 load at winter regional peak, and decreased generation from Cobb. (2025 and 2027)
  - SS2 – Low USI generation with high summer demand as described in South Island Backbone study with Grid Zone 9 load at summer regional peak, and decreased generation at Cobb and Argle. (2024 and 2026)
  - SS7 – Light load summer night as described in South Island Backbone study with Grid Zone 9 load at regional summer night trough. (2024 and 2026) This case was not considered for voltage stability limits as voltage collapse is unlikely during low load.

## 13.4 Contingencies under intact network conditions (N-1)

Table 13-1 below shows the circuits/transformers that would cause network violations within Grid Zone 9 if tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 13-1: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measures | Additional Notes |
|---|---|---|---|---|
| STK T7 220/110/11kV interconnecting transformer | Low voltage at BLN 110 and STK 66. | Winter all years and summer 2026, high load. | Remove KIK reactor, adjust ISL voltage setpoint, and switch on GYM caps. | To fix supply voltages, BLN33 caps must be added as well as tapping up supply transformers. (In addition to Operational measures). |
| KIK 110 kV Reactor R182 (50 Mvar) | Overvoltage at STK66. | Summer all years, light load. | Lower ISL and KIK voltage setpoints. | See Overvoltage section |

## 13.5 Overvoltage analysis during light load

The low load summer night scenario (SS7) causes overvoltage issues when the Kikiwa reactor is out of service. Adjusting the Islington and Kikiwa voltage setpoints will fix voltage issues on the 220 kV and 110 kV networks, but further action must be taken to maintain voltages within Code limits. The following actions must all be taken together to ensure all supply voltages remain within limits after loss of the Kikiwa reactor under intact network conditions:

- Switch out ISL-KIK 1 220 kV circuit;
- Tap down interconnecting transformers into Grid Zone 9 and Grid Zone 12;
- Tap down supply transformers in Grid Zone 9 and Grid Zone 12

## 13.6 Voltage stability studies

Voltage stability was studied in Grid Zone 9 for the SS1 and SS2 study conditions. The following N-1 contingencies were studied:

- DOB-GYM 1 66 kV circuit
- ISL-KIK 1, 2 or 3 220 kV circuit
- ISL SVC9 static Var compensator
- 1 x Blenheim 33 kV 20.4 Mvar capacitor
- 1 x Stoke 33 kV 40 Mvar capacitor

No voltage stability issues were detected for any of the above contingencies meaning the voltage stability load limit is above the load forecast with significant margin.

# 14 Grid Zone 10 and 11

## 14.1 Network overview

Grid Zone 10 is the Christchurch region and is bordered by Islington in the south and Waipara in the north. This region is supplied by 220 kV and 66 kV transmission circuits with interconnecting transformers at Islington and Waipara. It is a key region in the upper South Island with respect to reactive power sources, including static capacitors, shunt reactor, and two Static Var Compensators (SVCs) installed at Islington substation. These reactive power sources improve the network voltage and voltage stability performance of the upper South Island as a whole. Static capacitors are installed at Southbrook for the same purpose.

Grid Zone 11 is the Canterbury region. This region is served by four 220 kV circuits coming from the Otago region (Grid Zone 13) and terminating at Islington substation in the Christchurch region (Grid Zone 10). These 220 kV circuits form the critical backbone supplying most of the power to Grid Zones 9, 10, 11 and 12. In previous years Grid Zone 11 has also been interconnected to Grid Zone 13 via the 110 kV circuit between Timaru and Studholme in summer when the split at Studholme was closed. The system split at Studholme will now be open all year. Generators in the region include Tekapo A, Highbank, and Opuha hydro.

The Christchurch and Canterbury regions are shown geographically and as a single line diagram in Figure 14-1 and Figure 14-2, respectively.

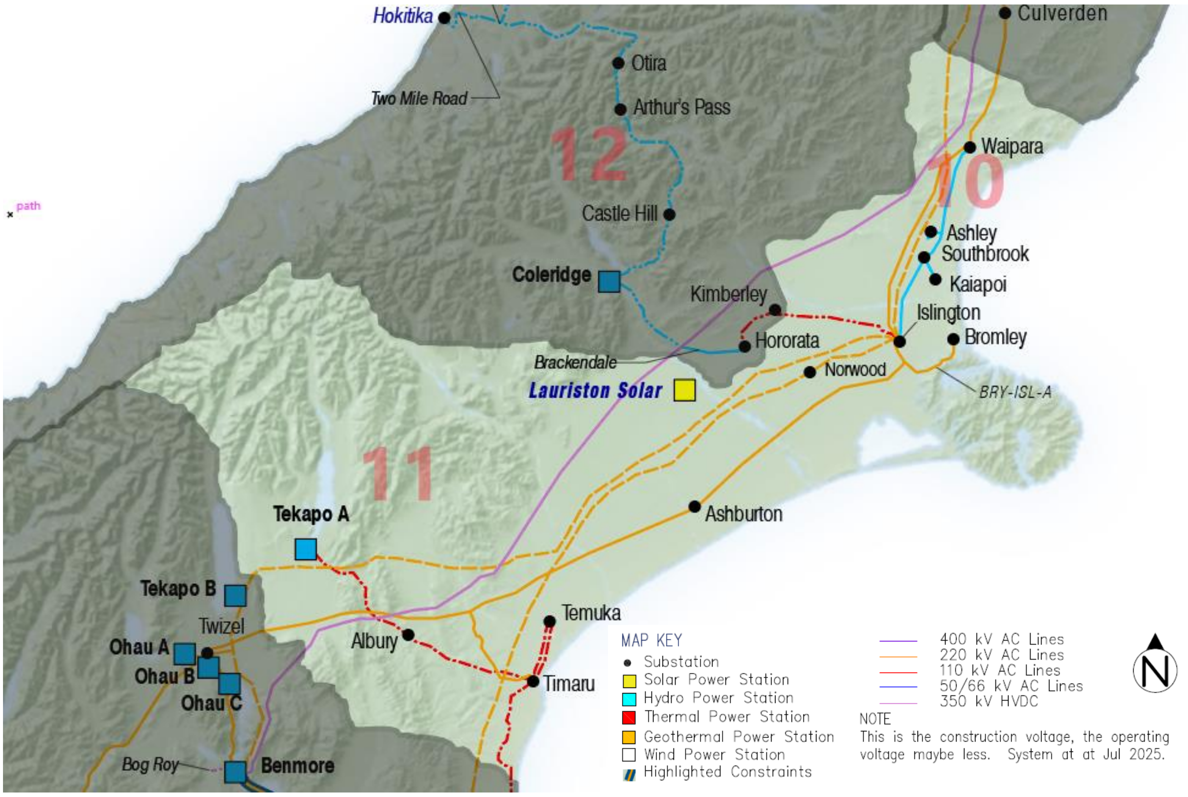


Figure 14-1: Geographic representation of Grid Zones 10 and 11

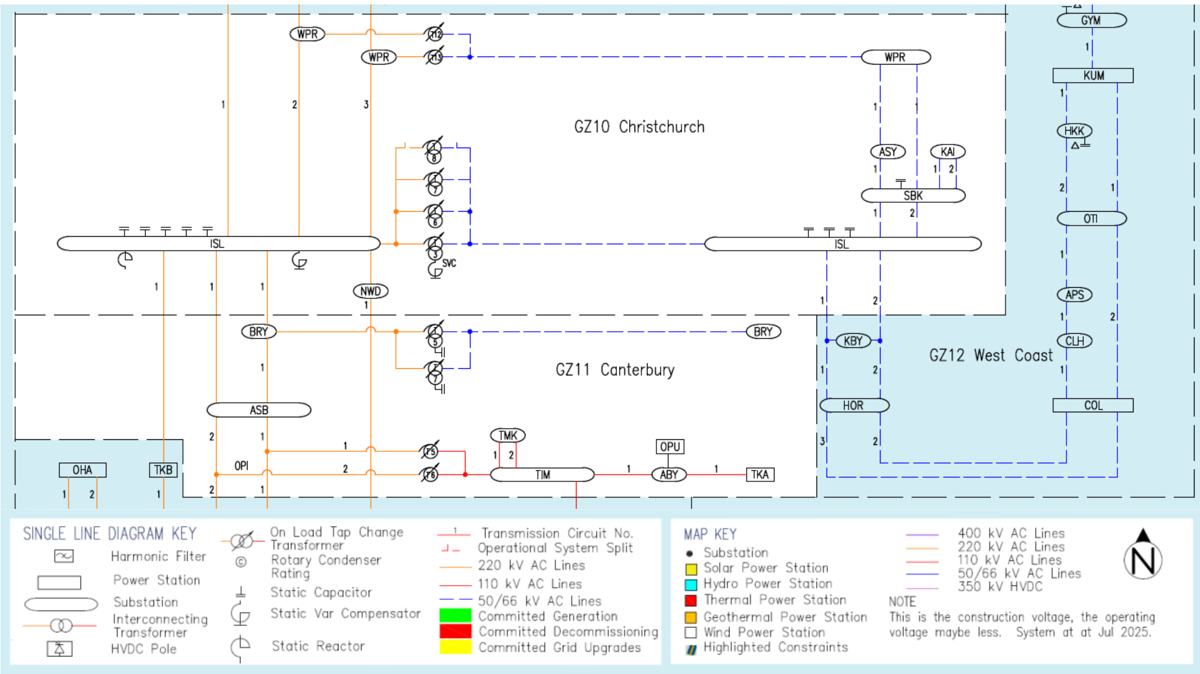


Figure 14-2: Single line diagram of Grid Zones 10 and 11

## 14.2 Committed projects and upgrades

The committed grid upgrades and generation in the Grid Zone over the period of study are shown in Table 14-1 and Table 14-2.

Table 14-1: Summary of committed upgrades

| Asset | Changes | Commissioning Date |
|---|---|---|
| Timaru 220/110 kV interconnecting Transformer Replacement | Timaru T8A and T8B replaced 1 x 250 MVA 10% Z Unit. | Commissioned |
| KAI-TF1 and TF2 branch limit | Upgrade the KAI-TF1 and TF2 11kV branch limit | Dec-2025 |

Table 14-2: Summary of committed generation

| Generation Plant (Owner) | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|
| Lauriston (Genesis) | Solar | 47 | Ashburton | Commissioned |

## 14.3 Assumptions and background

The following assumptions were made for Grid Zones 10 and 11 studies, unless otherwise specified in the detailed study notes:

- Southbrook 66 kV capacitor (35 Mvar), off in summer
- The 110 kV Network is permanently split at Studholme, with Studholme supplied from Timaru in summer and Waitaki in winter.
- Highbank generation is assumed to be unable to provide reactive support.
- The TMK Supply Transformer Overload Protection Scheme is available and enabled
  - Timaru T3 is available on hot standby for N-1 security
- The following scenarios were used for the N-1 security study of these regions:
  - SS1 – Low USI generation with high winter demand. This is as described in the South Island Backbone Study with Grid Zone 10 and 11 respectively at their regional peak, with low Tekapo A generation
  - SS2 – Low USI generation with high summer demand. This is as described in the South Island Backbone Study with Grid Zone 10 and 11 respectively at their regional peak, with low Tekapo A generation.

## 14.4 Contingencies under intact network conditions (N-1)

Table 14-3 shows the circuits that would cause network violations within Grid Zone 10 and 11 if tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 14-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| ASB-TIM-TWZ-1 or 2 220 kV Circuit | Low voltage at Timaru Area 110 kV, 33 kV and 33 kV Buses. | Summer all years. | Pre-Contingent TIM-T8 or T5 Tap change respectively. With no TKA Generation the minimum tap position is 11. | Requires post contingent tap change at low voltage sites to assist in correcting undervoltage. |
| TIM-TMK 1 or 2 110 kV circuit | Overloading of TIM-TMK-2 or 1 110 kV circuits respectively. | Summer all years. | TMK Supply Transformer Overload Protection Scheme operates to resolve overload. | |

# 15 Grid Zone 12

## 15.1 Network overview

Grid Zone 12 in the West Coast region is the area bordered by, and including, Dobson in the north and Kimberly in the south-east. Power is predominantly supplied to the region through 110 kV and 66 kV transmission circuits, with two interconnecting transformers at Dobson. There are local generators at Kumara and Coleridge. Static capacitors are installed at the Greymouth and Hokitika substations to improve the network voltage and voltage stability performance.

The West Coast is shown geographically in Figure 15-1 and as a single line diagram in Figure 15-2.

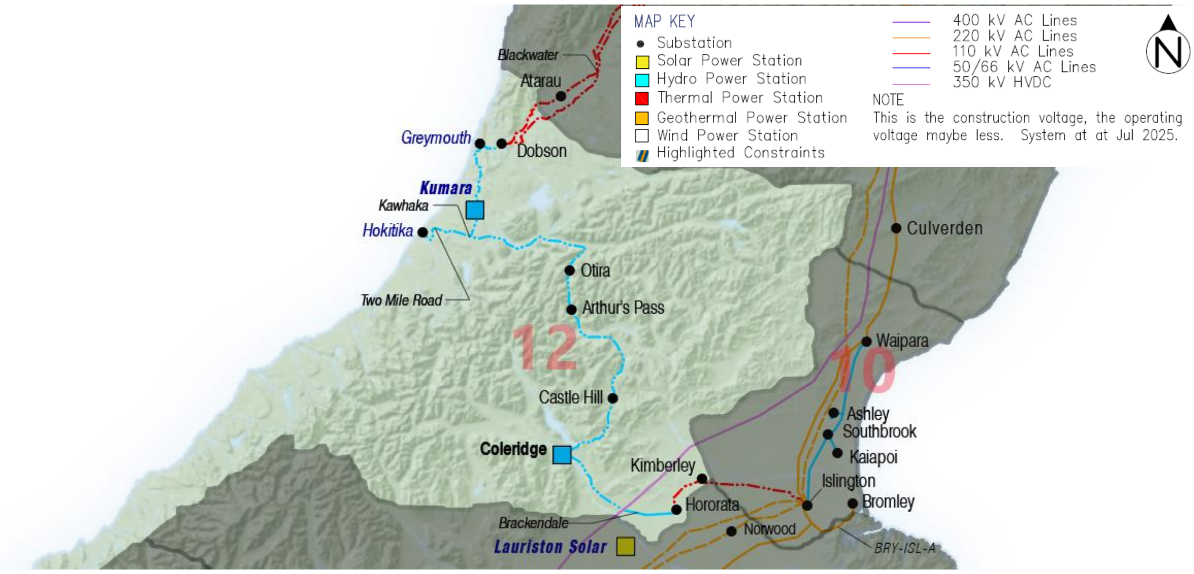


Figure 15-1: Geographic representation of Grid Zone 12

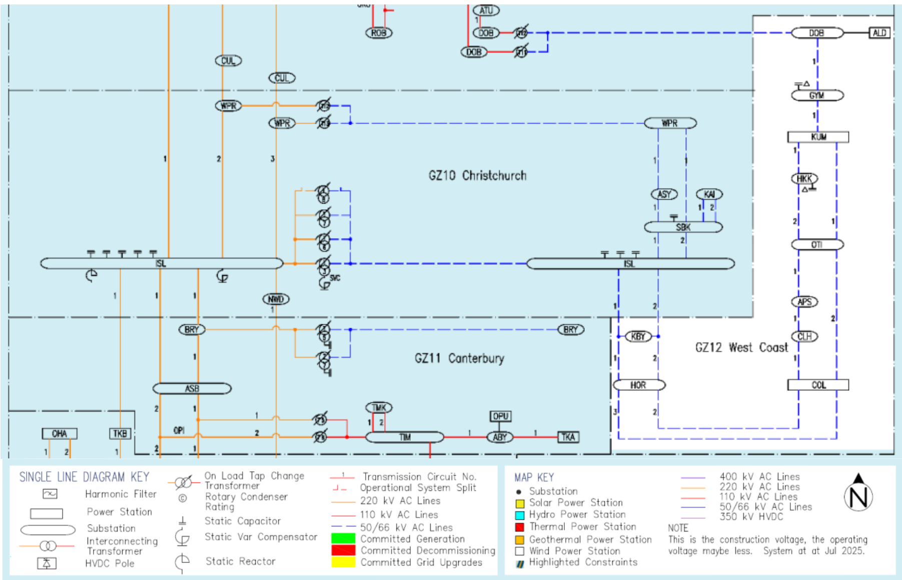


Figure 15-2: Single line diagram of Grid Zone 12

## 15.2 Committed projects and upgrades

There are no committed upgrades in Grid Zone 12 for the study period.

## 15.3 Assumptions and background

The following assumptions were made for Grid Zone 12 studies:

- All reactive power devices in the region were assumed to be available for all study cases including Islington C15, which is due to return to service in July 2024. However, it was not necessary to switch in Islington C15 for any of the studied years or contingencies.
- Major generators assumed to be available for voltage support were:
  - Coleridge generation
  - Kumara (KUM) generation was netted into local load for this study and so was only considered for MW and not MVAr voltage support.
- The HOR Automatic Under-Voltage Load Shedding Scheme assumed to be operational and enabled as normal.
- The following study scenarios were developed to determine security issues and transfer limits for Grid Zone 12:
  - SS1 – Low USI generation with high winter demand as described in South Island Backbone study with Grid Zone 12 load at winter regional peak, and decreased generation from Coleridge.
  - SS2 – Low USI generation with high summer demand as described in South Island Backbone study with Grid Zone 12 load at summer regional peak, and decreased generation at Coleridge.
  - SS7 – Light load summer night as described in South Island Backbone study with Grid Zone 12 load at regional summer night trough. This case was not considered for voltage stability limits as voltage collapse is unlikely during low load.

## 15.4 Contingencies under intact network conditions (N-1)

No violations were reported for contingencies under intact network conditions in Grid Zone 12. This is largely due to Wider Voltage Agreements (WVAs) which allow lower voltages in much of the 66 kV network. These WVAs reflect an understanding that the standard voltage Code limits for 66 kV networks cannot be reasonably achieved in the region.

## 15.5 Voltage stability studies

Voltage stability was studied in Grid Zone 12 for the SS1 and SS2 study conditions. All contingencies in this analysis were studied with a permanent system split between Dobson and Greymouth. The following contingencies were studied:

- COL-HOR 2 or 3 66 kV circuit
- All HKK 11 kV capacitors
- ISL SCV9 static var compensator

All studied contingencies in 2024, 2025, and 2026 had a voltage stability load limit of at least 110 percent of forecasted load (including the Dobson-Greymouth split and 5 percent margin, as with all load limits reported in this section). For SS1 (Winter regional peak load 2027), the Dobson-Greymouth split voltage stability load limit[13] was 103 percent of forecasted load. The contingencies studied concurrently with the Dobson-Greymouth split had the following results:

- COL-HOR 2 or 3 66 kV contingencies caused instability at just over 100% of forecast load
- ISL SCV9 contingency did not have any effect, voltage instability remained at 103% of forecasted load
- HKK Capacitors contingency caused voltage instability at 92.2% of forecasted load

This value under 100% from the HKK capacitors contingency does not represent an N-1 violation as it was studied concurrently with Dobson-Greymouth split. The recommended operational measure in this scenario is to constrain on Coleridge generation to provide voltage support. This contingency was re-run with all Coleridge generation on and voltage instability did not occur until 100.6% of forecasted load.

[13] *With 5% voltage stability margin applied*

# 16 Grid Zone 13

## 16.1 Network Overview

Grid Zone 13 comprises the Otago region. The region is connected from the north by the HVDC link into Benmore, three 220 kV circuits into Twizel, one 220 kV circuit from Islington (Norwood) to Livingston. A 110 kV circuit connecting Timaru to Studholme is in service, however a split is in place year-round, with Studholme supplied from Timaru during summer and from Waitaki during winter. Three 220 kV circuits enter the region from the south: two circuits from Clyde and one from Roxburgh. There are 220/110 kV interconnecting transformers at Waitaki and Cromwell supplying the 110 kV network.

There are hydro generation stations located at Tekapo, Ōhau, Benmore, Aviemore and Waitaki.

The Otago region is shown geographically and as a single line diagram in Figure 16-1 and Figure 16-2 respectively.

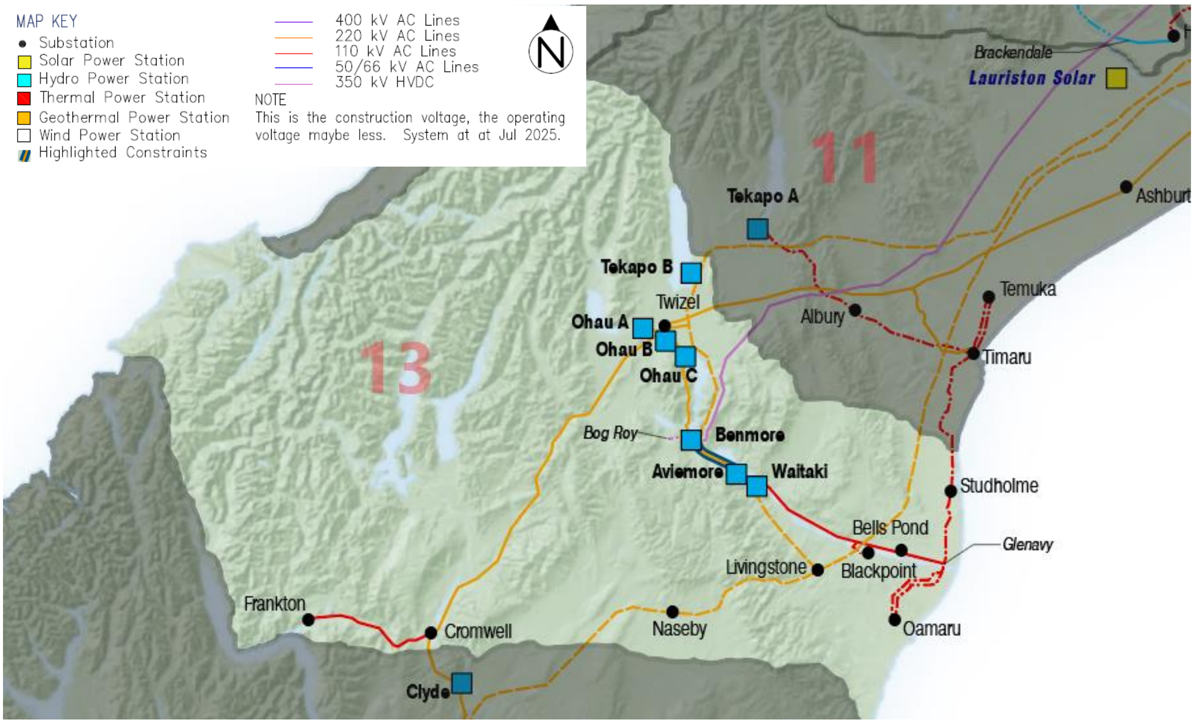


Figure 16-1: Geographic representation of Grid Zone 13

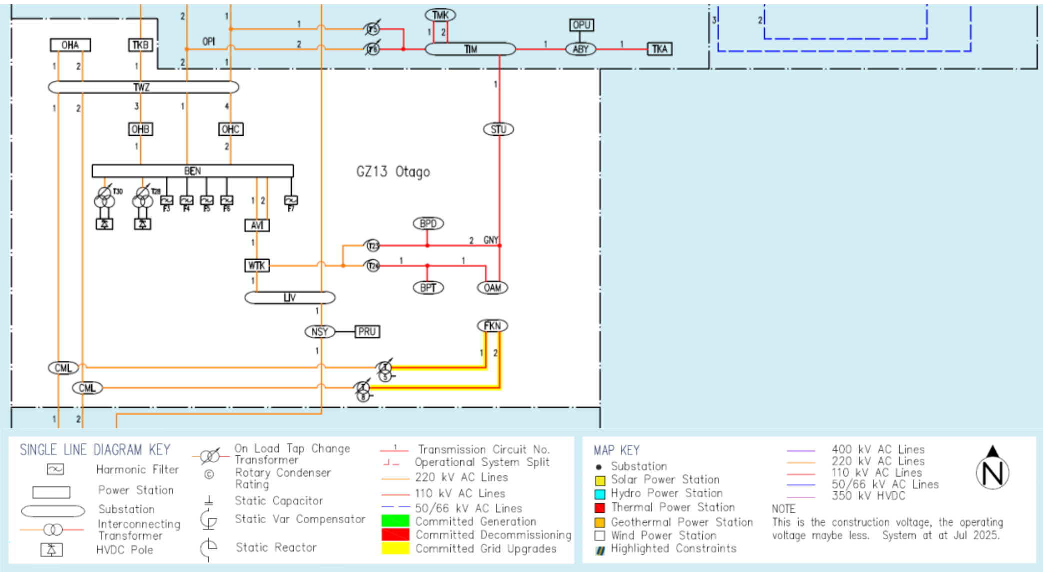


Figure 16-2: Single line diagram of Grid Zone 13

## 16.2 Committed projects and upgrades

The committed grid project in the Grid Zone over the period of study is shown in Table 16-1. There are no committed generation/storage projects in the Grid Zone over the period of study.

Table 16-1: Summary of committed upgrade

| Asset | Changes | Commissioning Date |
|---|---|---|
| Frankton Supply Transformer Upgrade | Frankton T4, T2A and T2B supply transformers upgraded to 2 x 120 MVA, 10% Z units. | Commissioned |
| CML-FKN 110 kV circuit upgrade | Thermal upgrade of CML-FKN 1 & 2 circuits to 100degC to increase Frankton transmission capacity | April-2026 |

## 16.3 Assumptions and background

The following assumptions were made for Grid Zone 13 studies unless otherwise specified separately in the report:

- Studholme is supplied from Waitaki in Winter, with the 110 kV connection between Studholme and Timaru open.
- Studholme is supplied from Timaru in summer, with the 110 kV connection between Studholme and Glenavy open.
- The OAM-WTK Circuit Overload Protection Scheme and OAM Circuit Overload Protection Scheme are available and are normally enabled during summer with Studholme supplied from Timaru. Both are disabled in winter with Studholme supplied from Waitaki.
- The CML-FKN Circuit Overload Protection Scheme is available and is normally enabled.
- The AVI-BEN Circuit Overload Protection Scheme is available and is normally enabled.
- The FKN Circuit Overload Protection Scheme is available and is normally enabled.

- HVDC transfer was used for generation balancing and varied for north and south transfer scenarios respectively.
- Oscillatory and Transient Angular stability constraints on the power export from Southland with Tiwai exit are not considered. These limits may constrain lower South Island generation before the voltage and thermal issues identified in this report, particularly for planned outages of 220 kV circuits connecting Roxbrugh, Naseby and Twizel. For more information on these emerging constraints, please refer to Transpower's report Impact of Tiwai exit | Transpower.

Two generation scenarios were considered, and generation dispatch and HVDC transfer used for each scenario are shown in Table 16-2.

Table 16-2: Generation dispatch and HVDC transfer assumptions for each scenario

| Generation Scenario | Grid Zone 13 Otago Generation (MW) including HVDC | | Grid Zone 14 Southland Generation (MW) including HVDC | | HVDC Flow (MW) | | | |
|---|---|---|---|---|---|---|---|---|
| | Summer (All years) | Winter (All years) | Summer (All years) | Winter (All years) | Summer 2024 | Summer 2026 | Winter 2025 | Winter 2027 |
| A - High lower South Island generation | 403/337 | 386/375 | 1613/1798 | 1717/1902 | 1003 (North) | 1069 (North) | 1023 (North) | 1034 (North) |
| B – Low lower South Island generation | 1477/1458 | 1299/1407 | 795/795 | 1165/1165 | 804 (South) | 785 (South) | 558 (South) | 667 (South) |

## 16.4 Contingencies under intact network conditions (N-1)

Table 16-3 shows the circuits/transformers that would cause network violations within Grid Zone 13 if they tripped under an intact network scenario, with all circuits / interconnecting transformers in-service. It also outlines the operational measures likely to be taken to mitigate the effect of the contingency.

Table 16-3: Summary of contingencies under intact network conditions

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| AVI-BEN-1 or 2 220 kV circuit | Overload of the remaining AVI-BEN 220 kV circuit. | Summer - Low Otago and Southland generation. Summer – High Otago and Southland generation. | Implement security constraint to increase generation south of Aviemore. Enable AVI-BEN COPS. | AVI-BEN COPS will not assist with this overload during south flow. |
| CYD-CML-TWZ-1 or 2 circuit 220 kV circuit or CML T8 or T5A/5 220/110 kV | Overload of CML-FKN 1 or 2 110 kV circuits. Undervoltage at FKN 110 kV bus. | Winter all years. | Under voltage is resolved with CML T8, T5A, T5B tap adjustment. FKN COPS triggers and | The new Frankton supply transformers alleviate the voltage stability in Frankton (see section 16.5). |

| Contingency | Effect of Contingency | Scenario | Operational Measure | Additional Notes |
|---|---|---|---|---|
| interconnecting transformers | | | resolves overload of lines. | It also alleviates the overload of the remaining supply transformer from a contingency of the other.<br>Comment (June minor update):<br>This will alleviate the overloading of CML-FKN 110 kV circuits. |
| OAM-BPT-WTK 1 or OAM-STU-BPD-WTK 2 110 kV circuits or WTK T24 or T23 220/110 kV interconnecting transformers | Overload of BDT-WTK 2 or BPC-WTK 1 110 kV circuits. Low voltage at Waitaki 110 kV buses. | Summer all years. | OAM-WTK COPS and the Oamaru Transformer Reverse Flow Protection Scheme operates and alleviates the overload. | |
| OHB-TWZ 3 or OHC-TWZ 4 220 kV circuits | Overload of BEN-TWZ-1 220 kV circuit. | Summer - Low Otago and Southland generation. | Apply security constraints to limit Benmore or the HVDC transfer. | |

## 16.5 Voltage stability studies

The previous SSF found that the voltage stability in Frankton will start to bind after Winter 2025 when the 5% voltage stability margin is applied. With the Frankton supply transformers being replaced before Winter 2025, the stability limit is found to increase by 38 MW as shown in Table 16-4. This is considerably above the forecasted loads for the region. The voltage stability load limit was applied with 5% margin.

Table 16-4: Voltage stability load limit at Cromwell and Frankton

| Binding Contingency | Year | Load Forecast at Cromwell and Frankton (MW) | Voltage Stability Load Limit Existing Frankton Supply Transformers (MW) | Voltage Stability Load Limit with the Upgraded Frankton Supply Transformers (MW) |
|---|---|---|---|---|
| CYD-CML-TWZ-1 or 2 circuit 220 kV circuit or CML T8 or T5A/5 220/110 kV interconnecting transformers | 2025 | 131.7 (FKN 80.8) | 129 | 167 |
| | 2027 | 142.2 (FKN 87.5) | 129 | 166 |

# 17 Grid Zone 14

## 17.1 Network overview

Grid Zone 14 is located at the bottom of the South Island and includes all circuits and stations into and south of Clyde. Grid Zone 14 is connected to the north by two 220 kV circuits between Clyde and Twizel and one 220 kV circuit between Naseby and Roxburgh. There are 220/110 kV interconnecting transformers at Halfway Bush, Roxburgh, Invercargill, and Gore.

Generation within the region includes hydro generation at Clyde, Manapouri, Roxburgh, and Waipori and wind generation at Mahinerangi, Kaiwera Downs and White Hill. Reactive support comprises capacitor banks at Balclutha, Brydone, and North Makarewa.

The Southland region is shown geographically and as a single line diagram in Figure 17-1 and Figure 17-2.

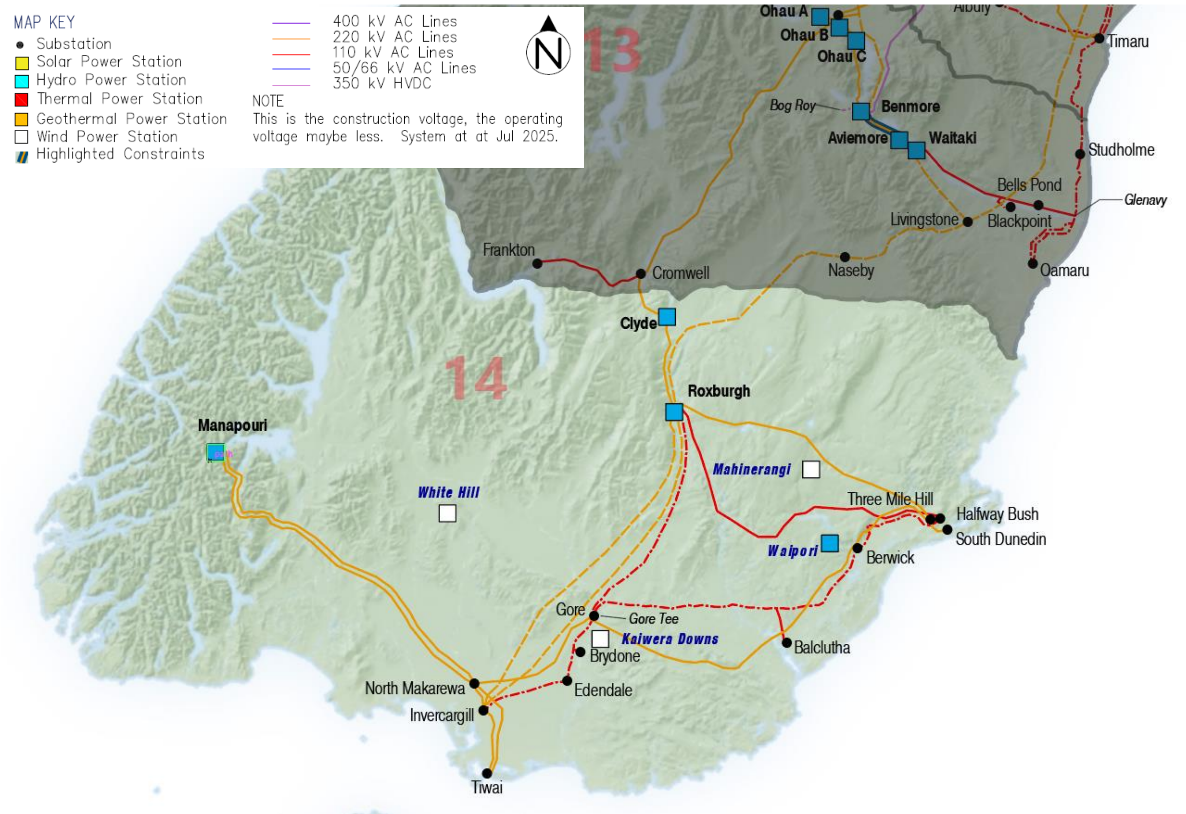


Figure 17-1: Geographic representation of Grid Zone 14

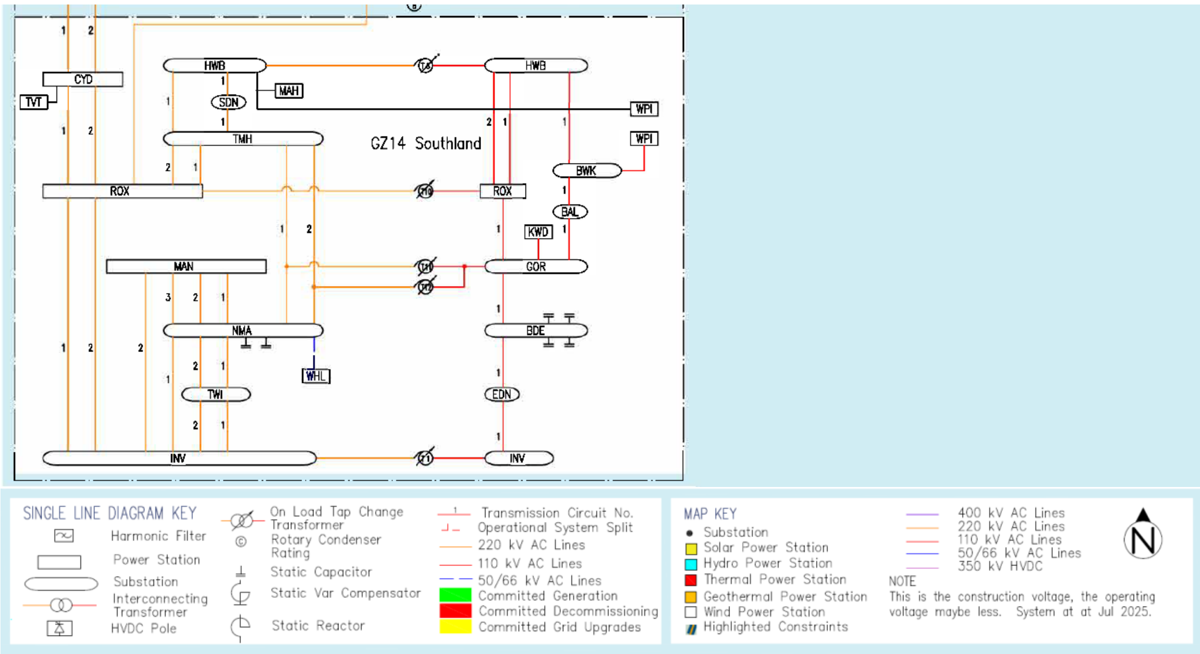


Figure 17-2: Single line diagram of Grid Zone 14

## 17.2 Committed projects and upgrades

The committed grid upgrades and generation project in the Grid Zone over the period of study is shown in Table 17-1 and Table 17-2. ~~There are no committed grid projects in the Grid Zone over the period of study.~~

Table 17-1: Summary of committed generation/storage

| Generation Plant (Owner) | Region | Type | Operating Capacity (MW) | Grid Injection Point | Commissioning Date |
|---|---|---|---|---|---|
| Kaiwera Downs Stage 2 | Southland | Wind | 152 | Kaiwera | 2026 |

Table 17-2: Summary of committed grid upgrades

| Asset | Changes | Commissioning Date |
|---|---|---|
| New INV 66 kV GXP | New 66 kV bus and 220/66 kV supply transformer for Powernet at INV to support electrification in the area | Commissioned |

## 17.3 Assumptions and background

The following assumptions were made for Grid Zone 14 studies, unless specified separately:

- The HWB T6 Reverse Power Protection scheme is operational, normally disabled.
- GRO Circuit Overload Protection Scheme is operational, normally disabled.
- All the Balclutha 2 x 4 Mvar, Brydone 4 x 5.15 Mvar and North Makarewa 2 x 50 Mvar capacitors are available for use.

- The Gore bus split is assumed to be normally closed.
- Tiwai Smelter assumed to be not retiring.
- Generation scenarios studied are listed in Table 17-3.

Table 17-3: Generation scenarios

| Generation Scenario | Southland Generation Summer (MW) | Southland Generation Winter (MW) |
|---|---|---|
| A - High Southland generation with max wind | 1613/1764 | 1717/1902 |
| B - Low Southland generation with no wind | 795/795 | 1165/1165 |
| C - Light load (low overnight trough generation with no wind) | 473/473 | 443 |

## 17.4 Contingencies under intact network conditions (N-1)

In the previous SSF Grid Zone 14 faced challenges, especially concerning the potential exit of the Tiwai Smelter or its continued operation alongside the anticipated connection of a new, significant industrial load at North Makarewa. However, in the current SSF, it has been projected that the Tiwai Smelter will maintain operations throughout the study period, as the load forecast reveals no signs of an impending exit. Additionally, the expected magnitude of the new industrial load has been revised downwards, rendering it less substantial than initially projected for the SSF's study duration. Consequently, the scenario analyses for Grid Zone 14 did not uncover any specific issues.

## 17.5 Voltage stability studies

The voltage stability studies show that voltage stability load limit is well beyond the load forecast for the study period. For clarity two voltage stability transfer limits are presented where "VSAT boundary" is defined as the region encompassing Manapouri, Tiwai and Invercargill. "Grid Zone 14 zone boundary" is defined as the interface of GZ 14 with rest of the South Island power system.

| Binding Contingency | Scenario | Voltage Stability Transfer Limit | Voltage Stability Load Limit | Additional Notes |
|---|---|---|---|---|
| CYD-CML-TWZ-2 220 kV circuit | Winter 2027, low Lower South Island Generation | 510 MW (VSAT boundary)<br>828 MW (Grid Zone 14 zone boundary) | 485MW | |

Voltage stability significantly deteriorates due to the lack of generation in the lower South Island caused by dry conditions. To maintain the voltage stability load limit above the winter peak load of 389 MW (excluding TWI load), it is essential to dispatch at least two Manapouri units and one Clyde unit on TWD.

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