

# Thermal generation decommissioning

Transpower's *Upper North Island Operational Limits* report

3 June 2016

## Contents

|                                                                                                                                                                  |          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>Executive summary</b>                                                                                                                                         | <b>1</b> |
| <b>1 Introduction</b>                                                                                                                                            | <b>2</b> |
| 1.1 Purpose of the paper                                                                                                                                         | 2        |
| 1.2 Futures contract prices for 2019 have dropped slightly and are in line with other long-dated futures contracts                                               | 2        |
| <b>2 Transpower’s report modelled the power system with and without the Rankine units</b>                                                                        | <b>3</b> |
| <b>3 Transpower’s 18 May 2016 observations indicate that the extension of the Rankine units alleviates or defers most (but not all) of Transpower’s concerns</b> | <b>3</b> |
| <b>4 Questions for the SRC to consider</b>                                                                                                                       | <b>4</b> |
| <b>Appendix A: Transpower’s <i>Upper North Island Operational Limits</i> report</b>                                                                              | <b>5</b> |
| <b>Appendix B: Transpower’s 18 May 2016 observations on the impact of retaining the Rankine units on the operation of the power system</b>                       | <b>6</b> |
| Introduction                                                                                                                                                     | 6        |
| Impact of Retaining Rankine Units on Operation of the Power System                                                                                               | 6        |
| Upper North Island Operational Limits                                                                                                                            | 6        |
| Conclusion                                                                                                                                                       | 7        |
| Impact of Retaining Rankine Units on Grid Investment Analysis Work Programme                                                                                     | 7        |
| Conclusion                                                                                                                                                       | 7        |
| Impact of Retaining Rankine Units on Security of Supply                                                                                                          | 7        |
| Conclusion                                                                                                                                                       | 8        |

## Executive summary

The function of the Security and Reliability Council (SRC) is to provide advice to the Electricity Authority (Authority) on the performance of the electricity system and the system operator, and reliability of supply issues.

Because of the security and reliability implication, the SRC wants to be kept up to date on developments pertaining to the decommissioning of thermal generation. The SRC has received papers at its 22 October 2015 and 15 March 2016 meetings that described the impact of thermal generation decommissioning announcements made in late 2015.

Since the SRC's 15 March 2016 meeting:

- Transpower has released the *Upper North Island Operational Limits* report that analysed the implications for the operation of the power system arising from the decommissioning and expected decommissioning of North Island thermal generation
- Genesis Energy has announced its intention to continue to operate its Huntly Rankine thermal units until December 2022.

This paper presents Transpower's report and its subsequent observations on the implications of Genesis's announcement.

Transpower's conclusions are that the retention of the Rankine units for a further four years:

- alleviates the situation identified in the report where it could have been difficult to meet New Zealand's electricity needs from 2019 onwards as a result of operational limits in the transmission system. The expected forecast demand can be met, assuming all assets in service and with normal market constraints in dispatch, until the Rankine units are decommissioned
- has changed the need date for investment in voltage support, but not by the full four years. There should be just enough time to deliver a solution to meet the investment need. Transpower plans to release a request for information on possible non-transmission solutions in winter 2016
- has significantly reduced the security of supply risk.

# 1 Introduction

## 1.1 Purpose of the paper

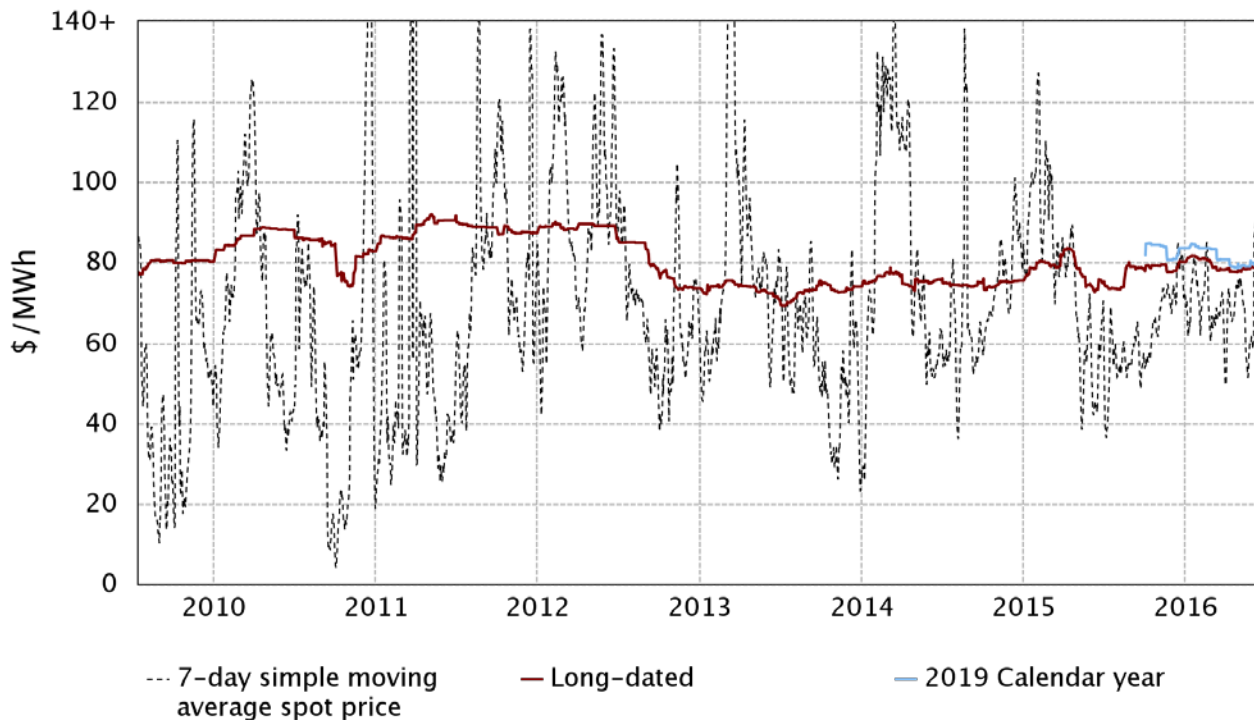
- 1.1.1 The Security and Reliability Council (SRC) has been appointed, in accordance with the Electricity Industry Act 2010 (Act), to provide independent advice to the Electricity Authority (Authority) on:
- a) the performance of the electricity system and the system operator
  - b) reliability of supply issues.
- 1.1.2 To this end, the SRC received reporting at its 22 October 2015 and 15 March 2016 meetings that described the impact of thermal generation decommissioning announcements made in late 2015.<sup>1</sup>
- 1.1.3 The purpose of this paper is to provide the SRC with a copy of Transpower's *Upper North Island Operational Limits* report for discussion. That report is the fourth in a series of reports by Transpower on the impact of thermal generation decommissioning.
- 1.1.4 The report was released by Transpower on 27 April. However, on 28 April Genesis Energy announced its decision to extend the operation of the Huntly Rankine units until December 2022. While this announcement pushes out the date by which the Rankine units are expected to be retired, it does not alter the underlying fact that there is a time where the power system will need to be operated without the Rankine units.

## 1.2 Futures contract prices for 2019 have dropped slightly and are in line with other long-dated futures contracts

- 1.2.1 The trend observed at the 22 October 2015 and 15 March 2016 SRC meetings for 2019 ASX forward prices to be very slightly (~\$5/MWh) above the long-term average has not continued. That gap has instead narrowed to less than \$1.25/MWh since 8 April 2016.
- 1.2.2 Figure 1 shows the forward price trends with the 2019 year separated out (in blue) to highlight the market reaction to the thermal generation decommissioning announcements. The futures prices for 2019 are barely elevated at all, which suggests that the industry believes 2019 does not present any special risk compared to other long-dated futures contracts.

<sup>1</sup> The closure announcements related to Contact Energy's Otahuhu unit, Mighty River Power's Southdown station and the Huntly Rankine units owned by Genesis Energy.

Figure 1 - ASX trading for New Zealand electricity futures



emi.ea.govt.nz/r/kr4h2

Source: Electricity Authority

Notes: 1. Source data is available from [www.emi.ea.govt.nz](http://www.emi.ea.govt.nz)

## 2 Transpower's report modelled the power system with and without the Rankine units

2.1.1 Transpower's report (attached as appendix A) concludes that if the Rankine units remain available "operational measures are not expected to be required for managing thermal capacity or voltage stability issues until beyond 2020."

## 3 Transpower's 18 May 2016 observations indicate that the extension of the Rankine units alleviates or defers most (but not all) of Transpower's concerns

3.1.1 Given the significance of Genesis' 28 April 2016 announcement, Transpower provided an overview of the implications for the SRC. These observations are included as appendix B.

3.1.2 Transpower's conclusions are that the retention of the Rankine units by the market for a further four years:

- a) alleviates the situation when it could have been difficult to meet New Zealand's electricity needs from 2019 onwards as a result of operational limits on the transmission system. The expected forecast demand can be met, assuming all assets in service and with normal market constraints in dispatch, until the Rankine units are decommissioned
- b) has changed the need date for investment in voltage support, but not by the full four years. There should be just enough time to deliver to meet the investment need. A request for information on non-transmission solutions is planned for release in winter 2016

c) has significantly reduced the security of supply risk.

#### 4 Questions for the SRC to consider

4.1.1 The SRC is asked to consider and provide advice on the following questions in the context of information security in New Zealand's electricity industry:

- |            |                                                                                                                                                                                                                                                                                                                      |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Q1.</b> | Does the SRC consider that Transpower's <i>Upper North Island Operational Limits</i> report would have provided, in the absence of the subsequent Genesis announcement, sufficient transparency of information to enable industry players and investors to make the most-informed decisions given the circumstances? |
| <b>Q2.</b> | Does the SRC agree with Transpower's 18 May 2016 observations and conclusions?                                                                                                                                                                                                                                       |
| <b>Q3.</b> | What further information, if any, does the SRC wish to have provided to it by the secretariat?                                                                                                                                                                                                                       |
| <b>Q4.</b> | What advice, if any, does the SRC wish to provide to the Authority?                                                                                                                                                                                                                                                  |

## **Appendix A: Transpower's *Upper North Island Operational Limits* report**

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# **Upper North Island Operational Limits**

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**Following Huntly Rankine unit retirements**

**April 2016**

**TRANSPower**





| Version | Date       | Change                 |
|---------|------------|------------------------|
| 1.0     | 22/04/2016 | Report for publication |

## 2

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**IMPORTANT**

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**Contents**

1     Executive Summary.....4

2     Upper North Island thermal capacity and voltage stability study ..... 11

3     Descriptions of scenarios ..... 19

Appendix A:   Study assumptions and approach ..... 22

Appendix B:   Analysis results plotted against forecast load duration curves ..... 30

Appendix C:   Operational measures ..... 34

# 1 EXECUTIVE SUMMARY

This report on Upper North Island power system limits is the fourth in a series of reports by Transpower to inform the electricity industry of potential implications arising from thermal generation de-commissionings, following recent and planned closures of a number of generation plants in the North Island.

Transpower finds that:

- If the Huntly Rankine units are decommissioned<sup>1</sup> in 2018, operational measures may be required to manage both thermal capacity and voltage stability issues during contingency and outage conditions in the upper North Island (Zone 1)<sup>2</sup> in winter.
- Although the upper North Island power system will be more susceptible to risk exposures without the Rankine units, in 2018 the identified thermal capacity and voltage stability issues can be managed satisfactorily with transmission and generation assets currently in service and available to the market by utilising existing operational measures<sup>3</sup>, however in 2019 and 2020 there is a risk that load management may be required at peak times.

This report outlines the indicative operational limits<sup>4</sup> based on an onerous set of transmission network and operating conditions used to highlight thermal capacity and voltage stability issues.

Real time operational limits will vary depending on system conditions at the time and how any surplus or deficit of generation is dispatched at the time of the on-line assessment.

This report also describes how operational limits may vary if reactive or active power is injected at different locations in the North Island power system.

## 1.1 BACKGROUND

Transpower is considering three key issues relevant to the announced plant closures, specifically:

- Operational limits – understanding asset operational limits which determine how the existing and committed transmission network and generation must be managed to ensure system security is maintained.
- Potential investment options – understanding asset capability limits which determine whether there is a need to invest in new transmission infrastructure or

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<sup>1</sup> In late 2015, Genesis Energy has announced the two remaining coal fired Rankine units at Huntly power station will be permanently withdrawn from the electricity market by December 2018 (unless market conditions change).

<sup>2</sup> Upper North Island (Zone 1) is the combination of Auckland and Northland.

<sup>3</sup> Transpower's existing operational measures in the planning time frame include load and generation agreements and use of market node and voltage stability equation constraints. See Appendix C: for details.

<sup>4</sup> With a new system split assumed at Mataroa–Ohakune-1 110 kV circuit. This removed the Bunnythorpe–Mataroa-1 110 kV overloading issue identified in a previous study. The full report is published on the System Operator website or click here for "[Upper North Island Supply Study - Managing Peak Loads Following Southdown and Otahuhu Retirements \(updated 3rd Nov 2015\)](#)".

non-transmission options to facilitate the anticipated changes in transmission network and generation.

- Security of supply – understanding energy capacity issues which determine the ability of generation to meet peak winter demand, when inflows into hydro lakes are low and the ability to meet the peak demand in the North Island typically on a cold winter's evening.

This report covers the first of these issues. The second issue is covered in the "Upper North Island Generation Decommissioning" report published in March 2016<sup>5</sup>. The third issue has been covered in the "Security of Supply Analysis of Thermal Decommissioning" report published in December 2015<sup>6</sup>.

As System Operator, Transpower has assessed power system operational limits in a variety of scenarios for both thermal capacity and voltage stability issues related to the announced retirement of the Huntly Rankine units<sup>7</sup>.

These assessments are to inform participants of anticipated operational limits should the Rankine units be decommissioned in December 2018. These operational limits highlight North Island thermal capacity and upper North Island voltage stability issues under a high transfer to meet Zone 1 demand. Energy and reserve capacity issues are separately addressed and discussed in the "Security of Supply Analysis of Thermal Decommissioning" report<sup>8</sup>.

This report is intended for readers with a reasonable understanding of power system operation (particularly thermal capacity and voltage stability issues in the upper North Island region) and knowledge of Transpower's earlier reports on thermal generation decommissioning. A separate short overview has been provided to summarise the key points.

## 1.2 OPERATIONAL MEASURES OVERVIEW

Transpower is accountable for understanding how certain conditions impact the power system and responsible for taking operational measures in planning and real time to ensure, as system operator, it meets the Principle Performance Obligations (PPOs) set out in the Code<sup>9</sup>. Available operational measures include:

- Constraint equations. These are applied (generally in planning time) to the Scheduling Pricing Dispatch (SPD) tool to manage both thermal and voltage stability limits with all assets in service and accounting for expected planned outages – this is the default operational measure utilised by the System Operator.

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<sup>5</sup> The full report is published on the System Operator website or click here for "[Upper North Island Generation Decommissioning Report](#)".

<sup>6</sup> The full report is published on the System Operator website or click here for "[Security of Supply Analysis of Thermal Decommissioning Report](#)".

<sup>7</sup> Retirement of the last two Huntly Rankine units will remove 500 MW of thermal generation from the North Island (additional to the 550 MW of thermal generation decommissioned in 2015).

<sup>8</sup> Additional information regarding short term generation balance can be found on <http://www.nzgb.redspider.co.nz> or click here for "[New Zealand Generation Balance project](#)". Reports highlighting possible winter demand and generation issues are published on the System Operator website or click here for "[National Winter Group reports](#)".

<sup>9</sup> Electricity Industry Participate Code.

- Customer agreements for generation dispatch and/or load management. These are arranged in planning time by Transpower to ensure system load and generation availability to provide system conditions which support for planned outages.
- Ancillary service contracts for voltage and frequency support. These are arranged in planning time using the System Operator's Procurement Plan<sup>10</sup> process to enable compliance with the PPOs on an ongoing basis. Transpower annually (or more frequently, if required) reviews the need for such support services and contracts for the supply of services as required. For voltage support services, in particular, the contract is typically for multiple years and often requires material capital investment. Over frequency support is also contracted over multiple years. The quantity of service required is assessed by the System Operator once needs are identified.

During real time grid emergencies an additional operational measure is to shed load to avoid system failure that may arise from asset operation beyond declared limits or power system instability.

### 1.3 STUDY PROCESS

Transpower's studies examined the maximum transfer capability of the North Island power system into Zone 1 assuming all generation and transmission assets are in service and available for dispatch. A system split at Mataroa was assumed to remove the overload identified in earlier studies<sup>11</sup>. Projected load growth was modelled with a range of generation scenarios and credible contingencies to examine the maximum Zone 1 load that can be supplied without circuit overloads, bus voltage violations or voltage instability.

### 1.4 SUMMARY OF RESULTS

If the Rankine units are not decommissioned from the North Island power system, operational measures are not expected to be required for managing thermal capacity or voltage stability issues until beyond 2020<sup>12</sup>, under both contingency and outage conditions.

Following decommissioning of the Rankine units, existing operational measures can satisfactorily manage identified operational limits in 2018, with all assets in service and available for dispatch. However, the upper North Island power system will be at risk of load management at peak times in 2019 and 2020. It will also be more susceptible to risk exposures from high peak loads and extended or unplanned outages of assets such as generators, circuits or reactive support equipment. This situation is consistent with previous reports published by Transpower, including the December 2015 security of supply analysis. That analysis found peak load capacity risk in the North Island will

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<sup>10</sup> Procurement methodology and mechanisms are set out in Part 8 of the Code.

<sup>11</sup> Details of this overload are in the "[UNI Supply Study - Managing Peak Loads Following Southdown and Otahuhu Retirements](#)" report published on the System Operator website.

<sup>12</sup> The scope of this study was to examine thermal capacity and voltage stability issues which may arise between winter 2018 and 2020. For long term study results refer to the System Operator website or click here for "[Upper North Island Generation Decommissioning Report](#)".

increase if little new generation was built and Huntly Rankine units are decommissioned as announced, requiring load management in some circumstances to manage the entire upper North Island power system.

Previously, when this type of load management was forecast, industry and regional forums were established by Transpower<sup>13</sup> to assist determining optimised or preferred solutions to manage peak loads including voltage support contracts and demand side management. The need for such an approach for the upper North Island in 2019 and 2020 would be reviewed in the context of any wider North Island peak capacity issues.

### 1.4.1 Thermal and Voltage Stability Limits

#### 1.4.1.1 N-1 condition

If the Rankine units are decommissioned in 2018, then under the restricted generation scenario<sup>14</sup> operational measures are expected to be required for management of a loss of Huntly Unit 5 generation for approximately 0.2% of the time or 8 hours<sup>15</sup> per year in winter 2019.

Table 1 shows the operational limits under the restricted generation scenario for N-1, operating condition. The most onerous limit is in bold.

*Table 1 N-1 operational limit summary from winter 2018 onwards*

| Year                      | Zone 1 Island Expected Peak load Forecast | Contingency Condition | Thermal Capacity Issues | Voltage Stability Issues | Zone 1 Operational Limits Rankine units out of service | % of time forecast <sup>16</sup> exceeds limit |
|---------------------------|-------------------------------------------|-----------------------|-------------------------|--------------------------|--------------------------------------------------------|------------------------------------------------|
| Winter 2018               | 2282 MW<br>308 MVar                       | N-1                   | No                      | No                       | Above load forecast                                    | --                                             |
| Summer/Shoulder 2018/2019 | 2282 MW<br>308 MVar                       | N-1                   | No                      | No                       | Above load forecast                                    | --                                             |
| Winter 2019               | 2313 MW<br>312 MVar                       | N-1                   | No                      | <b>Yes</b>               | <b>Voltage Stability Limit: 2290 MW</b>                | <b>0.2%</b>                                    |
| Summer/Shoulder 2019/2020 | 1791 MW<br>334 MVar                       | N-1                   | No                      | No                       | Above load forecast                                    | --                                             |
| Winter 2020               | 2342 MW<br>316 MVar                       | N-1                   | No                      | <b>Yes</b>               | <b>Voltage Stability Limit: 2290 MW</b>                | <b>0.8%</b>                                    |

In winter 2018:

- the load forecast<sup>17</sup> is not expected to exceed Zone 1 thermal and voltage stability limits for N-1 condition.

<sup>13</sup> Transpower as system operator facilitates any electricity industry coordination for managing security of supply issues.

<sup>14</sup> Three generation scenarios were studied, namely, restricted, typical and unrestricted. See Section 3 for details. The restricted generation scenario presents the most onerous thermal overload and voltage stability limits for power transfer into Zone 1.

<sup>15</sup> Calculated from % of time the winter load forecast exceeded the limit, then multiplied by the number of hours per year or minutes per day in the winter season.

<sup>16</sup> % of the time is given based on Load Duration Curves defined in Appendix A.5. % of time is rounded to the nearest decimal value.

<sup>17</sup> Based on the published Zone 1 winter expected load forecast values from Transpower's "[2015 Transmission Planning Report](#)". See Appendix A.5 for details.

- the load forecast is expected to exceed both Zone 1 thermal and voltage stability limits for N-G-1 condition; operational measures would be required for approximately 4.2% and 0.8% of the time, respectively. The thermal limit is expected to bind before the voltage stability limit.
- the load forecast is expected to exceed Zone 1 voltage stability limit for N-1-1 condition; operational measures would be required for approximately 2.3% of the time.

Results for outage and N-1 contingency conditions are presented in a similar manner.

#### 1.4.1.2 Outage and N-1 condition

##### 1.4.1.2.1 Huntly unit 5 outage

If the Rankine units are decommissioned in 2018, then under the restricted generation scenario<sup>18</sup>, operational measures are expected to be required for management of a generation outage of Huntly Unit 5 and a loss of Pakuranga-Whakamaru-1 or 2 220 kV circuit (N-G-1) for approximately 5.2% of the time or 75 minutes per day in winter 2019 during this outage<sup>19</sup>.

Table 2 shows the operational limits under the restricted generation scenario for N-G-1, operating condition. The most onerous limit is in bold.

*Table 2 N-G-1 operational limit summary from winter 2018 onwards*

| Year                      | Zone 1 Island Expected Peak load Forecast | Contingency Condition | Thermal Capacity Issues | Voltage Stability Issues | Zone 1 Operational Limits Rankine units out of service            | % of time forecast <sup>20</sup> exceeds limit |
|---------------------------|-------------------------------------------|-----------------------|-------------------------|--------------------------|-------------------------------------------------------------------|------------------------------------------------|
| Winter 2018               | 2282 MW<br>308 MVar                       | N-G-1                 | <b>Yes</b>              | Yes                      | <b>Thermal Limit: 2100 MW</b><br>Voltage Stability Limit: 2200 MW | <b>4.2%</b><br>0.8%                            |
| Summer/Shoulder 2018/2019 | 2282 MW<br>308 MVar                       | N-G-1                 | No                      | No                       | Above load forecast                                               | --                                             |
| Winter 2019               | 2313 MW<br>312 MVar                       | N-G-1                 | <b>Yes</b>              | Yes                      | <b>Thermal Limit: 2100 MW</b><br>Voltage Stability Limit: 2200 MW | <b>5.2%</b><br>2%                              |
| Summer/Shoulder 2019/2020 | 1791 MW<br>334 MVar                       | N-G-1                 | No                      | No                       | Above load forecast                                               | --                                             |
| Winter 2020               | 2342 MW<br>316 MVar                       | N-G-1                 | <b>Yes</b>              | <b>Yes</b>               | <b>Thermal Limit: 2100 MW</b><br>Voltage Stability Limit: 2200 MW | <b>6.3%</b><br>2.9%                            |

##### 1.4.1.2.2 Pakuranga-Whakamaru-1 or 2 220 kV circuit outage

If the Rankine units are decommissioned in 2018, then under the restricted generation scenario<sup>21</sup>, operational measures are expected to be required for management of a

<sup>18</sup> Three generation scenarios were studied, namely, restricted, typical and unrestricted. See Section 3 for details. The restricted generation scenario presents the most onerous thermal overload and voltage stability limits for power transfer into Zone 1.

<sup>19</sup> Planned Outage Co-ordination Process database showed Huntly Unit 5 outages were usually planned for summer with a typical outage period of 1 to 3 days. The longest confirmed outage was 14 days in December 2007.

<sup>20</sup> % of the time is given based on Load Duration Curves defined in Appendix A.5. % of time is rounded to the nearest decimal value.

transmission circuit outage of Pakuranga-Whakamaru-1 or 2 220 kV circuit and a loss of Huntly Unit 5 generation (N-1-1) for approximately 3.4% of the time or 48 minutes per day in winter 2019 during this outage<sup>22</sup>.

Table 3 shows the operational limits under the restricted generation scenario for N-1-1, operating condition. The most onerous limit is in bold.

*Table 3 N-1-1 operational limit summary from winter 2018 onwards*

| Year                      | Zone 1 Island Expected Peak load Forecast | Contingency Condition | Thermal Capacity Issues | Voltage Stability Issues | Zone 1 Operational Limits Rankine units out of service | % of time forecast <sup>23</sup> exceeds limit |
|---------------------------|-------------------------------------------|-----------------------|-------------------------|--------------------------|--------------------------------------------------------|------------------------------------------------|
| Winter 2018               | 2282 MW<br>308 MVar                       | N-1-1                 | No                      | Yes                      | <b>Voltage Stability Limit: 2160 MW</b>                | <b>2.3%</b>                                    |
| Summer/Shoulder 2018/2019 | 2282 MW<br>308 MVar                       | N-1-1                 | No                      | No                       | Above load forecast                                    | --                                             |
| Winter 2019               | 2313 MW<br>312 MVar                       | N-1-1                 | No                      | Yes                      | <b>Voltage Stability Limit: 2160 MW</b>                | <b>3.4%</b>                                    |
| Summer/Shoulder 2019/2020 | 1791 MW<br>334 MVar                       | N-1-1                 | No                      | No                       | Above load forecast                                    | --                                             |
| Winter 2020               | 2342 MW<br>316 MVar                       | N-1-1                 | No                      | Yes                      | <b>Voltage Stability Limit: 2160 MW</b>                | <b>4.2%</b>                                    |

If the Rankine units are decommissioned earlier than announced, in winter 2018 rather than summer, then under the restricted generation scenario operational measures are expected to be required for management of outage and N-1 contingency conditions, as follows:

- a generation outage of Huntly Unit 5 and a loss of Pakuranga-Whakamaru-1 or 2 220 kV circuit (N-G-1) for approximately 4.2% of the time or 60 minutes a day in winter 2018 during this outage;
- a transmission circuit outage of Pakuranga-Whakamaru-1 or 2 220 kV circuit and a loss of Huntly Unit 5 generation (N-1-1) for approximately 2.3% of the time or 30 minutes a day in winter 2018 during this outage.

### 1.4.2 Thermal capacity sensitivity results

Thermal limits are sensitive to generation and load profiles. Slight variations in load and generation dispatch configurations may alter the limiting contingency for transferring power into Zone 1 between the identified 220 kV circuits north of Bunnythorpe and Stratford, namely Huntly-Stratford-1, Tokaanu-Whakamaru-1 or 2, Stratford-Taumaranui-1, Taumarunui-Te Kowhai-1 and Bunnythorpe-Tangiwhai-1.

Increasing central North Island generation or introducing new generation in the Taranaki and South Waikato region failed to alleviate any of the identified Zone 1 thermal limits.

<sup>21</sup> Three generation scenarios were studied, namely, restricted, typical and unrestricted. See Section 3 for details. The restricted generation scenario presents the most onerous thermal overload and voltage stability limits for power transfer into Zone 1.

<sup>22</sup> Planned Outage Co-ordination Process database showed Pakuranga-Whakamaru-1 or 2 220 kV circuit outages were usually planned for summer with a typical outage period of 1 to 2 days. The longest confirmed outage was 2 days in December 2015.

<sup>23</sup> % of the time is given based on Load Duration Curves defined in Appendix A.5. % of time is rounded to the nearest decimal value.



Increasing generation in the Wairakei area transferred thermal capacity issues to Atimauri-Whakamaru-1 or Te Mihi-Whakamaru-1 220 kV circuit.

The thermal capacity sensitivity results showed, under the studied system condition and generation scenario, irrespective of which contingency set the identified thermal limit, the limit itself is not expected to change significantly.

### 1.4.3 Voltage stability sensitivity results

The Zone 1 voltage stability limit is sensitive to both active and reactive power injection. Table 4 shows the voltage stability sensitivity analysis results for active and reactive power injection at various locations in the North Island. The improvement ratio shows the MW change in Zone 1 voltage stability limit for one additional MW or MVar injected at a specific bus.

*Table 4 Voltage stability sensitivity summary*

| Type of Injection        | Location                                           | Summer Improvement Ratio <sup>24</sup> | Winter Improvement Ratio |
|--------------------------|----------------------------------------------------|----------------------------------------|--------------------------|
| Reactive Power Injection | Huntly 220 kV bus                                  | 0.51                                   | 0.28                     |
| Reactive Power Injection | Southdown 220 kV bus                               | 0.57                                   | 0.41                     |
| Reactive Power Injection | Maraetai 220 kV bus                                | 0.09                                   | 0.03                     |
| Reactive Power Injection | Kaitaia 110 kV bus.                                | 0.31                                   | 0.18                     |
| Reactive Power Injection | Albany 220 kV bus                                  | 0.67                                   | 0.37                     |
| Active Power Injection   | Haywards 220 kV bus                                | --                                     | --                       |
| Active Power Injection   | Huntly 220 kV bus                                  | 0.57                                   | 0.68                     |
| Active Power Injection   | Southdown 220 kV bus                               | 0.63                                   | 0.86                     |
| Active Power Injection   | Stratford 220 kV bus                               | --                                     | --                       |
| Active Power Injection   | Between Carrington Street and Stratford 110 kV bus | --                                     | --                       |
| Active Power Injection   | Between Te Kowhai and Taumarunui 220 kV bus        | 0.29                                   | 0.45                     |

Voltage stability sensitivity results showed, under the studied system conditions and generation scenarios, active and reactive power injection at buses closer to the upper North Island region is more effective in alleviating Zone 1 voltage stability limit when compared to more distant injection.

<sup>24</sup> Improvement ratio is the average increase (between the restricted, typical and unrestricted generation scenarios) of Zone 1 voltage stability limit to per MW or MVar injected at a relevant bus location. "--" indicates no observable impact to Zone 1 voltage stability limits.

## 2 UPPER NORTH ISLAND THERMAL CAPACITY AND VOLTAGE STABILITY STUDY

### 2.1 INTRODUCTION

Managing Zone 1 operational limits during peak loads requires consideration of two elements, namely thermal capacity and voltage stability.

Thermal capacity is the ability of the transmission network to transfer required active and reactive power without exceeding asset stated capability.

Voltage stability is the ability of the transmission network to provide active and reactive power to maintain bus voltages within operational limits.

This report presents analysis undertaken to assess thermal capacity and voltage stability issues during Zone 1 peak load following decommissioning of the Rankine units.

Sensitivity of Zone 1 voltage stability limits to additional active and reactive power injection at various North Island bus locations is also included.

A high-level discussion on potential operational measures for managing identified operational limits is in Appendix C:.

### 2.2 RESULTS - THERMAL CAPACITY ASSESSMENT

This section outlines Zone 1 thermal capacity assessment results, under N-1 and a planned generation outage scenario (N-G-1) of Huntly Unit 5 or a planned circuit outage (N-1-1) of Pakaruranga-Whakamaru-1 or 2 220 kV circuit. Identified thermal limits are compared to the Expected Island Load Forecast values for Zone 1 (defined in Section A.5).

If the Rankine units were to stay in service, the seasonal load forecasts are not expected to exceed Zone 1 thermal limits under all studied system conditions until beyond 2020.

#### 2.2.1 Summer thermal limits

Following decommissioning of the Rankine units, under either N-1, N-G-1 or N-1-1 operating conditions, the summer load forecast is not expected to exceed Zone 1 thermal limits until beyond 2020 (1791 MW)<sup>25</sup>.

Table 5 presents the current and forecast Zone 1 thermal limits identified for the summer period, when the Rankine units are in or out of service. Depending on the load and generation configuration, any one of the three identified limiting contingencies could set the Zone 1 load limit.

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<sup>25</sup> See Appendix B.1 for summer thermal limits plotted against Zone 1 load forecast.

*Table 5 Summer thermal limit summary*

| Contingency Condition                                      | Potential Limiting Contingency            | Respective Thermal Capacity Issues                                                    | Zone 1 Maximum MW<br>Rankine units in service | Zone 1 Maximum MW<br>Rankine units out of service |
|------------------------------------------------------------|-------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------------------|---------------------------------------------------|
| N-1                                                        | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                     | 2700                                          | 2200 <sup>26</sup>                                |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanau-Whakamaru-1 or 2 220 kV circuit                   |                                               |                                                   |
|                                                            | Huntly-Stratford-1 220 kV circuit         | Huntly-Te Kowhai-1 or Taumarunui- Te Kowhai-1 or Stratford-Taumarunui-1 220kV Circuit |                                               |                                                   |
| N-G-1:<br>Huntly Unit 5 outage                             | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                     | 2300                                          | 1850                                              |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanau-Whakamaru-1 or 2 220 kV circuit                   |                                               |                                                   |
|                                                            | Huntly-Stratford-1 220 kV circuit         | Huntly-Te Kowhai-1 or Taumarunui- Te Kowhai-1 or Stratford-Taumarunui-1 220kV Circuit |                                               |                                                   |
| N-1-1:<br>Pakuranga-Whakamaru-1 or 2 220 kV circuit outage | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                     | 2625                                          | 2125                                              |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanau-Whakamaru-1 or 2 220 kV circuit                   |                                               |                                                   |
|                                                            | Pakuranga-Whakamaru-2 or 1 220 kV circuit | Otahuhu-Whakamaru-1 or 2 220 kV circuit                                               |                                               |                                                   |

### 2.2.2 Shoulder thermal limits

Following decommissioning of the Rankine units, the shoulder load forecast is not expected to exceed Zone 1 thermal limits under N-1, N-G-1 or N-1-1 operating conditions until beyond 2020 (1875 MW)<sup>27</sup>.

Table 6 presents the current and forecast Zone 1 thermal limits identified for the shoulder period when the Rankine units are in and out of service. Depending on the load and generation configuration, any one of the three identified limiting contingencies could set the Zone 1 load limit.

*Table 6 Shoulder thermal limit summary*

| Contingency Condition | Potential Limiting Contingency        | Respective Thermal Capacity Issues | Zone 1 Maximum MW<br>Rankine units in service | Zone 1 Maximum MW<br>Rankine units out of service |
|-----------------------|---------------------------------------|------------------------------------|-----------------------------------------------|---------------------------------------------------|
| N-1                   | Stratford-Taumarunui-1 220 kV circuit | Huntly-Stratford-1 220 kV circuit  | 2850                                          | 2350                                              |

<sup>26</sup> Thermal capacity sensitivity analysis showed Zone 1 thermal limit has a positive sensitivity of 0.935 to per MW of Rankine unit generation. If only one Rankine unit is retired, this will increase the identified thermal limits by approximately 234 MW.

<sup>27</sup> See Appendix B.2 for shoulder thermal limits plotted against Zone 1 load forecast.

| Contingency Condition                                      | Potential Limiting Contingency            | Respective Thermal Capacity Issues                                                     | Zone 1 Maximum MW Rankine units in service | Zone 1 Maximum MW Rankine units out of service |
|------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------|------------------------------------------------|
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanau-Whakamaru-1 or 2 220 kV circuit                    |                                            |                                                |
|                                                            | Huntly-Stratford-1 220 kV circuit         | Huntly-Te Kowhai-1 or Taumarunui- Te Kowhai-1 or Stratford-Taumarunui-1 220 kV circuit |                                            |                                                |
| N-G-1:<br>Huntly Unit 5 outage                             | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                      | 2450                                       | 2050                                           |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanau-Whakamaru-1 or 2 220 kV circuit                    |                                            |                                                |
|                                                            | Huntly-Stratford-1 220 kV circuit         | Huntly-Te Kowhai-1 or Taumarunui- Te Kowhai-1 or Stratford-Taumarunui-1 220 kV Circuit |                                            |                                                |
| N-1-1:<br>Pakuranga-Whakamaru-1 or 2 220 kV circuit outage | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                      | 2800                                       | 2300                                           |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanau-Whakamaru-1 or 2 220 kV circuit                    |                                            |                                                |
|                                                            | Pakuranga-Whakamaru-2 or 1 220 kV circuit | Otahuhu-Whakamaru-1 or 2 220 kV circuit                                                |                                            |                                                |

### 2.2.3 Winter thermal limits

Following decommissioning of the Rankine units, the winter load forecast is not expected to exceed Zone 1 thermal limits under N-1 or N-1-1 operating conditions until beyond 2020 (2342 MW)<sup>28</sup>.

However, if the Rankine units are decommissioned earlier than scheduled, in winter 2018, the winter load forecast (2282 MW) is expected to exceed Zone 1 thermal limit under N-G-1 operating conditions for approximately 4.2% of the time<sup>29</sup> and increase to 6.3% by 2020.

Table 7 presents the current and forecast Zone 1 thermal limits identified for the winter period when the Rankine units are in and out of service. Depending on the load and generation configuration, any one of the three identified limiting contingencies could set the Zone 1 load limit.

<sup>28</sup> See Appendix B.3 for winter thermal limits plotted against Zone 1 load forecast.

<sup>29</sup> Based on seasonal Zone 1 Load Duration Curve defined in Appendix A.5.

Table 7 Winter thermal limit summary

| Contingency Condition                                      | Potential Limiting Contingency            | Respective Thermal Capacity Issue                                                     | Zone 1 Maximum MW Rankine units in service | Zone 1 Maximum MW Rankine units out of service |
|------------------------------------------------------------|-------------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------|------------------------------------------------|
| N-1                                                        | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                     | 2900                                       | 2400                                           |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanu-Whakamaru-1 or 2 220 kV circuit                    |                                            |                                                |
|                                                            | Huntly-Stratford-1 220 kV circuit         | Huntly-Te Kowhai-1 or Taumarunui- Te Kowhai-1 or Stratford-Taumarunui-1 220kV circuit |                                            |                                                |
| N-G-1:<br>Huntly Unit 5 outage                             | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                     | 2500                                       | 2100                                           |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanu-Whakamaru-1 or 2 220 kV circuit                    |                                            |                                                |
|                                                            | Huntly-Stratford-1 220 kV circuit         | Huntly-Te Kowhai-1 or Taumarunui- Te Kowhai-1 or Stratford-Taumarunui-1 220kV Circuit |                                            |                                                |
| N-1-1:<br>Pakuranga-Whakamaru-1 or 2 220 kV circuit outage | Stratford-Taumarunui-1 220 kV circuit     | Huntly-Stratford-1 220 kV circuit                                                     | 2850                                       | 2350                                           |
|                                                            | Tokaanu-Whakamaru-1 or 2 220 kV circuit   | Bunnythorpe-Tangiwhai-1 or Tokaanu-Whakamaru-1 or 2 220 kV circuit                    |                                            |                                                |
|                                                            | Pakuranga-Whakamaru-2 or 1 220 kV circuit | Otahuhu-Whakamaru-1 or 2 220 kV circuit                                               |                                            |                                                |

### 2.2.4 Thermal capacity sensitivity discussion

Thermal limits are sensitive to generation and load profiles. Slight variation in load and generation dispatch configuration may vary the limiting contingency for transferring power into Zone 1 between the identified 220 kV circuits north of Bunnythorpe and Stratford, namely, Huntly-Stratford-1, Tokaanu-Whakamaru-1 or 2, Stratford-Taumarunui-1, Taumarunui-Te Kowhai-1 and Bunnythorpe-Tangiwhai-1. The observed percentage loading on these circuits was within 5% of each other and depending on the circuit loading any one of the identified 220 kV circuits can become overloaded post-contingently.

Increasing central North Island generation<sup>30</sup>, particularly in the Wairakei area alleviates the identified thermal capacity issues, but transfers the thermal capacity issue on to either Atiamuri-Whakamaru-1 or Te Mihi-Whakamaru-1 220 kV circuits for a contingency of the other circuit.

<sup>30</sup> Central North Island loads also have an impact on Zone 1 thermal limits. If load demand in the Hamilton, Edgcombe or Taranaki region increases, the identified limits are expected to decrease.

Two scenarios<sup>31</sup> with new generation were examined to determine the influence on the identified Zone 1 thermal limits:

1. New Taranaki generation had no observable impact on any of the identified thermal limits, due to the injection location.
2. New south Waikato generation did impact the identified thermal limits, however this did not increase any of the identified thermal limits. The limiting contingency was the loss of Huntly-Stratford-1 220 kV circuit overloading Taumarunui-Te Kowhai-1 220 kV circuit, this was resolved by reducing generation south of this contingency to offset the additional generation injected in the region.

Thermal capacity sensitivity results under the studied system conditions and generation scenarios showed that, irrespective of which contingency sets the identified thermal limit, the limit itself is not expected to change significantly.

## 2.3 RESULTS - VOLTAGE STABILITY ASSESSMENT

This section outlines Zone 1 voltage stability assessment results, under N-1 and a planned generation outage (N-G-1) of Huntly Unit 5 or a planned circuit outage (N-1-1) of Pakaruranga-Whakamaru-1 or 2 220 kV circuit. Voltage stability limits are compared against the Expected Island Load Forecast values for Zone 1 (defined in Section A.5).

If the Rankine units stay in service, the seasonal load forecasts are not expected to exceed Zone 1 voltage stability limits under all studied operating conditions and generation scenarios until beyond 2020.

Three generation scenarios were studied, namely restricted, typical and unrestricted generation dispatch (defined in Section 3.2).

### 2.3.1 Summer voltage stability limits

Following decommissioning of the Rankine units, under all studied operating conditions and generation scenarios, the summer load forecast is not expected to exceed Zone 1 voltage limits until beyond 2020 (1791 MW)<sup>32</sup>.

Table 8 presents the current and forecast Zone 1 voltage stability limits identified for the summer period, under the three studied generation scenarios when the Rankine units are in and out of service.

*Table 8 Summer voltage stability limit summary*

| Contingency Condition | Generation scenario | Limiting Contingency | Zone 1 Maximum MW Rankine units in service | Zone 1 Maximum MW Rankine units out of service |
|-----------------------|---------------------|----------------------|--------------------------------------------|------------------------------------------------|
| N-1                   | Restricted          | Huntly Unit 5        | 2600                                       | 2270 <sup>33</sup>                             |
|                       | Typical             | Huntly Unit 5        | 2640                                       | 2320                                           |

<sup>31</sup> New generation scenarios are defined in Section 3.3.

<sup>32</sup> See Appendix B.1 for summer voltage stability limits plotted against Zone 1 load forecast.

<sup>33</sup> Voltage stability sensitivity analysis showed, in summer Zone 1 voltage stability limit has a positive sensitivity of 0.51 and 0.57 to per MW and MVar of Rankine unit generation, respectively.

| Contingency Condition                                      | Generation scenario | Limiting Contingency                      | Zone 1 Maximum MW Rankine units in service | Zone 1 Maximum MW Rankine units out of service |
|------------------------------------------------------------|---------------------|-------------------------------------------|--------------------------------------------|------------------------------------------------|
|                                                            | Unrestricted        | Huntly Unit 5                             | 2680                                       | 2390                                           |
| N-G-1:<br>Huntly Unit 5 outage                             | Restricted          | Pakuranga-Whakamaru-1 or 2 220 kV circuit | 2440                                       | 2080                                           |
|                                                            | Typical             | Pakuranga-Whakamaru-1 or 2 220 kV circuit | 2470                                       | 2110                                           |
|                                                            | Unrestricted        | Pakuranga-Whakamaru-1 or 2 220 kV circuit | 2510                                       | 2170                                           |
| N-1-1:<br>Pakuranga-Whakamaru-1 or 2 220 kV circuit outage | Restricted          | Huntly Unit 5                             | 2470                                       | 2110                                           |
|                                                            | Typical             | Huntly Unit 5                             | 2500                                       | 2170                                           |
|                                                            | Unrestricted        | Huntly Unit 5                             | 2500                                       | 2230                                           |

### 2.3.2 Winter voltage stability limits

Following decommissioning of the Rankine units, under N-1 operating conditions for typical and unrestricted generation scenarios, the winter load forecast is not expected to exceed Zone 1 voltage limits until beyond 2020 (2342 MW)<sup>34</sup>.

If the Rankine units are decommissioned in winter 2018, under the restricted generation scenario, the winter load forecast is expected to exceed Zone 1 voltage stability limits from:

- Winter 2019 (2313 MW) for N-1 operating condition, approximately 0.2% of the time in 2019, increased to 0.8% by 2020
- Winter 2018 (2282 MW) for N-G-1 operating condition, approximately 0.8% of the time in 2018, increased to 2.9% by 2020
- Winter 2018 (2282 MW) for N-1-1 operating condition, approximately 2.3% of the time in 2018, increased to 4.2% by 2020.

Under the typical generation scenario, the winter load forecast is expected to exceed Zone 1 voltage stability limits from:

- Winter 2018 (2282 MW) for N-G-1 operating condition, approximately 0.7% of the time in 2018, increased to 1.8% by 2020
- Winter 2018 (2282 MW) for N-1-1 operating condition, approximately 0.6% of the time in 2018, increased to 1.7% by 2020.

Under the unrestricted generation scenario, the winter load forecast is expected to exceed Zone 1 voltage stability limits from:

- Winter 2018 (2282 MW) for N-G-1 operating condition, approximately 0.2% of the time in 2018, increased to 1.3% by 2020
- Winter 2018 (2282 MW) for N-1-1 operating condition, approximately 0.2% of the time in 2018, increased to 1.3% by 2020.

<sup>34</sup> See Appendix B.3 for winter voltage stability limits plotted against Zone 1 load forecast.

Table 9 presents the current and forecast Zone 1 voltage stability limits identified for the winter period under the three studied generation scenarios when the Rankine units are in and out of service.

*Table 9 Winter voltage stability limit summary*

| Contingency Condition                                      | Generation scenario | Limiting Contingency                      | Zone 1 Maximum MW<br>HLY Unit1-2 in service | Zone 1 Maximum MW<br>HLY Unit1-2 out of service |
|------------------------------------------------------------|---------------------|-------------------------------------------|---------------------------------------------|-------------------------------------------------|
| N-1                                                        | Restricted          | Huntly Unit 5                             | 2740                                        | 2290 <sup>35</sup>                              |
|                                                            | Typical             | Huntly Unit 5                             | 2770                                        | 2390                                            |
|                                                            | Unrestricted        | Huntly Unit 5                             | 2800                                        | 2490                                            |
| N-G-1:<br>Huntly Unit 5 outage                             | Restricted          | Pakuranga-Whakamaru-1 or 2 220 kV circuit | 2520                                        | 2200                                            |
|                                                            | Typical             | Pakuranga-Whakamaru-1 or 2 220 kV circuit | 2590                                        | 2230                                            |
|                                                            | Unrestricted        | Pakuranga-Whakamaru-1 or 2 220 kV circuit | 2630                                        | 2250                                            |
| N-1-1:<br>Pakuranga-Whakamaru-1 or 2 220 kV circuit outage | Restricted          | Huntly Unit 5                             | 2530                                        | 2160                                            |
|                                                            | Typical             | Huntly Unit 5                             | 2590                                        | 2230                                            |
|                                                            | Unrestricted        | Huntly Unit 5                             | 2630                                        | 2250                                            |

## 2.4 VOLTAGE STABILITY SENSITIVITY ASSESSMENT

The Zone 1 voltage stability limit is sensitive to both active and reactive power injection. Table 10 shows the voltage stability sensitivity analysis results for active and reactive power injection at various locations in the North Island. The improvement ratio shows the MW change in Zone 1 voltage stability limit for one additional MW or MVar injected at a specific bus.

The improvement ratio given below is the average of the observed change in Zone 1 voltage stability limit under the restricted, typical and unrestricted generation scenarios. "--" indicates no observable change was seen when active or reactive power was injected at the corresponding bus location.

*Table 10 Voltage stability sensitivity summary*

| Type of Injection        | Location             | Summer Improvement Ratio | Winter Improvement Ratio |
|--------------------------|----------------------|--------------------------|--------------------------|
| Reactive Power Injection | Huntly 220 kV bus    | 0.51                     | 0.28                     |
| Reactive Power Injection | Southdown 220 kV bus | 0.57                     | 0.41                     |
| Reactive Power Injection | Maraetai 220 kV bus  | 0.09                     | 0.03                     |
| Reactive Power Injection | Kaitaia 110 kV bus.  | 0.31                     | 0.18                     |
| Reactive Power Injection | Albany 220 kV bus    | 0.67                     | 0.37                     |

<sup>35</sup> Voltage stability sensitivity analysis showed, in winter Zone 1 voltage stability limit has a positive sensitivity of 0.28 and 0.68 to per MW and MVar of Rankine unit generation, respectively.



| Type of Injection      | Location                                           | Summer Improvement Ratio | Winter Improvement Ratio |
|------------------------|----------------------------------------------------|--------------------------|--------------------------|
| Active Power Injection | Haywards 220 kV bus                                | --                       | --                       |
| Active Power Injection | Huntly 220 kV bus                                  | 0.57                     | 0.68                     |
| Active Power Injection | Southdown 220 kV bus                               | 0.63                     | 0.86                     |
| Active Power Injection | Stratford 220 kV bus                               | --                       | --                       |
| Active Power Injection | Between Carrington Street and Stratford 110 kV bus | --                       | --                       |
| Active Power Injection | Between Te Kowhai and Taumarunui 220 kV bus        | 0.29                     | 0.45                     |

**18**

The Zone 1 voltage stability limit has a higher sensitivity to reactive power injection at Albany 220 kV bus during both summer. It also has approximately the same sensitivity to reactive power injection at Southdown or Huntly 220 kV bus in summer, and is more sensitive to reactive power injection at Southdown 220 kV bus in winter. In general, reactive compensation is more effective when injected closer to the load centre.

Zone 1 voltage stability limit is more sensitive to active power injection at Southdown 220 kV bus in both summer and winter compared to when megawatts are injected further away from Zone 1.

### 3 DESCRIPTIONS OF SCENARIOS

This section describes the scenarios<sup>36</sup> studied for thermal capacity, voltage stability and voltage stability sensitivity assessment. It also provides high-level information on the approach used to conduct these assessments.

These assessments allow understanding of the impact of removing the active and reactive power injection of the two 250 MW Rankine units, and how the removal affects North Island thermal limits and Zone 1 voltage stability limits on the existing transmission network system.

#### 3.1 THERMAL CAPACITY STUDY SCENARIOS

The thermal capacity studies generation dispatch scenario was set up to highlight potential thermal capacity issues that could be seen when supplying Zone 1 peak demand.

The restricted generation dispatch assumed a less than optimal number of machines are available to inject power into the North Island power system. This was represented with:

- Central North Island generation<sup>37</sup> dispatched to 80%;
- Karapiro, Arapuni North hydro generation dispatched to 70%;
- Te Uku wind generation dispatched to 20%; and
- North Island wind generation to 50% of installed capacity.

To examine a credible range of dispatch scenarios, variations to the generation dispatch assumption in the central North Island were analysed to highlight potential thermal capacity issues under the restricted generation scenario. The overall central North Island generation dispatch level was maintained, however the individual generation level were varied at Whakamaru, Tokaanu, Wairakei, or Stratford power station.

Sensitivities with new generation in the Taranaki<sup>38</sup> and south Waikato<sup>39</sup> region were also analysed to examine the impact on identified thermal capacity issues.

#### 3.2 VOLTAGE STABILITY STUDY SCENARIOS

Voltage stability studies examined three generation scenarios (restricted, typical, and unrestricted). These scenarios were set up to highlight potential voltage stability issues that would be seen when supplying Zone 1 peak demand.

The restricted generation dispatch assumed a less than optimal number of machines available to inject power into the North Island power system. This was represented with thermal, geothermal and Tongariro hydro generation scheme dispatched at

<sup>36</sup> Different study scenarios were setup to examine thermal capacity and voltage stability issues individually.

<sup>37</sup> Central North Island is defined as Edgecumbe, Hawkes Bay and Taranaki regions.

<sup>38</sup> Generation injection site is assumed between Carrington Street and Stratford 110 kV bus.

<sup>39</sup> Generation injection site is assumed between Te Kowhai and Taumarunui 220 kV bus.

approximately 100%<sup>40</sup>, Waikato hydro generation scheme at 70%<sup>41</sup>, and wind generation at 0% of installed capacity.

The typical generation dispatch assumed a historical average number of machines available to inject power into the North Island power system. This was represented with thermal, geothermal and Tongariro hydro generation scheme dispatched at approximately 100%, Waikato hydro generation scheme at 80% and wind generation at 20%<sup>42</sup> of installed capacity.

The unrestricted generation dispatch assumed all North Island generation is available to inject power if required. This was represented with thermal, geothermal and Tongariro hydro generation scheme dispatched to approximately 100%, Waikato hydro generation scheme at 100%, and wind generation at 20% of installed capacity.

The Waikato hydro generation scheme is electrically close to the upper North Island region. This means its influence on Zone 1 voltage stability is greater than generation south of the Waikato region. By comparison, wind generation in the lower North Island and the HVDC link has minimal influence on voltage stability limits in the upper North Island region.

The Waikato hydro generation scheme<sup>43</sup> was set to different percentages of rated output for voltage stability assessment. The generation megawatt values chosen were a compromise between allowing for a severely restricted dry year generation scenario and being overly conservative. In the typical generation dispatch scenario, if the Waikato hydro generation scheme was set to generate at 60% of installed capacity (simulating a dry year scenario<sup>44</sup>) the voltage stability limit was reduced by 28% when compared to Waikato hydro generation scheme set at 80%.

### 3.3 VOLTAGE STABILITY SENSITIVITY STUDY SCENARIOS

For the voltage stability sensitivity analysis, the impact of active or reactive power injection at different bus locations in the North Island power system was examined. This provided an indication on the influence of geographical location of active and reactive power injection to the Zone 1 voltage stability limits. A number of scenarios were considered:

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<sup>40</sup> By comparison with the Waikato hydro generation scheme, the Tongariro scheme's influence on Zone 1 voltage stability is minimal. Therefore in the transfer analysis it was 'dispatched' to 100% of installed capacity.

<sup>41</sup> For the restricted and typical generation dispatch scenarios, the Waikato hydro generation scheme's megawatt output was fixed and not permitted to increase (or ramp higher than specified) during the transfer analysis. For the unrestricted dispatch scenario this generation was not permitted to decrease (or ramp lower than specified).

<sup>42</sup> North Island wind generation was 'dispatched' to 20% of its installed capacity, but made 100% available (if necessary). Whether or not the capacity was utilised in the simulation depended on the megawatt demand during the transfer analysis.

<sup>43</sup> Zone 1 voltage stability sensitivity to Waikato hydro generation scheme is approximately 0.3 in summer and 0.5 in winter per MW to per positive MW injection.

<sup>44</sup> Dry years significantly reduce the MW-hours from the Waikato hydro generation scheme, however Waikato generation's temporary peaking capability should still be available during a dry year.

1. Reactive power injection at Huntly 220 kV bus: this scenario assumed the two Rankine units at Huntly power station could be operated as synchronous condensers<sup>45</sup> providing voltage support for Zone 1 power transfer.
2. Reactive power injection at Southdown 220 kV bus: this scenario assumed three units at Southdown power station could be operated as synchronous condensers providing voltage support for Zone 1 power transfer.
3. Reactive power injection at Maraetai 220 kV bus: this scenario assumed two units at Maraetai power station were operated in tail-water depressed mode providing voltage support for Zone 1 power transfer.
4. Reactive power injection at Kaitaia 110 kV bus: this scenario assumed the static capacitors at Kaitaia 110 kV substation<sup>46</sup> were switched in.
5. Reactive power injection at Albany 220 kV bus: this scenario assumed new reactive support equipment is commissioned and injecting into the 220 kV bus.
6. Active power injection at Haywards 220 kV bus: this scenario assumed a maximum HVDC transfer level of 1200 MW to account for a potential Tiwai aluminum smelter closure.
7. Active power injection at Huntly 220 kV bus: this scenario assumed new generation is commissioned and injecting into the 220 kV bus.
8. Active power injection at Southdown 220 kV bus: this scenario assumed new generation is commissioned and injecting into the 220 kV bus.
9. Active power injection at Stratford 220 kV bus: this scenario assumed new generation is commissioned and injecting into the 220 kV bus.
10. Active power injection between Carrington Street and Stratford 110 kV bus: this scenario assumed new generation is commissioned and injecting into the 110 kV bus.
11. Active power injection between Te Kowhai and Taumarunui 220 kV bus: this scenario assumed new generation is commissioned and injecting into the 220 kV bus.

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<sup>45</sup> The technical challenges of converting of Huntly and Southdown generator to synchronous condensers are not considered in the study.

<sup>46</sup> From September 2015 operational control of Kaitaia 110 kV capacitors does not reside with Transpower. For prudent power system assessment the reactive power injection from the Kaitaia 110 kV capacitors was assumed at 0 MVar in the base-case.

## Appendix A: STUDY ASSUMPTIONS AND APPROACH

### A.1 SCOPE OF THE STUDY

This study was to assess thermal limits and voltage stability limits arising from transporting power north through the North Island to Zone 1 during peak load times taking into account the decommissioning of the Huntly Rankine units. These limits were assessed to N-1 (loss of the most significant transmission asset) and N-1-1 (loss of the most significant transmission asset during an outage of another) conditions.

The network was analysed to determine Zone 1 thermal and voltage stability limits. The limits were compared with load forecast from winter 2018 through to the end of winter 2020.

### A.2 THERMAL CAPACITY ASSESSMENT

Steady-state contingency analysis was used to identify the pre-event maximum megawatt transfer into Zone 1 without overloading stated asset capability rating<sup>47</sup> in the North Island for the most severe contingency under normal and outage operating conditions.

Each identified Zone 1 thermal limit utilises the 15-minute off-load time calculation<sup>48</sup> for transmission circuits (which allow real-time contingency management).

Power system thermal capacity assessment was conducted using the off-line version of the Transpower's real-time operational planning tool - Alstom SCADA STNET Study Time Contingency Analysis Tool (STCA).

### A.3 VOLTAGE STABILITY ASSESSMENT

Steady-state voltage stability analysis was undertaken to identify the pre-event maximum megawatt transfer into Zone 1 without exceeding the voltage stability limit for the most severe contingency, under normal and outage operating conditions.

Voltage collapse is a phenomenon which occurs after there is no longer enough reactive power available from any source in the network to support the increase in load and prevent collapse. In the upper North Island region, reactive support can be received from assets which are electrically close to the region, such as generators, capacitors, SVCs and STATCOMs.

Once these assets reach their limit, voltage collapse will occur with only a small subsequent increase in load beyond this previously secure operating point.

To identify the maximum load that can be supplied in Zone 1, the simulation load must be increased to the point at which voltage collapse occurs. The simulated load is then

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<sup>47</sup> Transmission assets typically have maximum continuous, seasonal and post-contingent ratings which can be different.

<sup>48</sup> The 15-minute off-load time calculation is utilised in both System Security Forecast studies and other thermal capacity assessments done by the System Operator.

stepped back to determine the voltage stability limit that should be applied for the studied transmission and operating conditions.

These studies were repeated with a variety of generation dispatch scenarios and outage combinations to identify the Zone 1 voltage stability limit.

Power system voltage stability assessment was conducted using the off-line version of Transpower's real-time operational planning tool – Powertech Voltage Security Assessment Tool (VSAT).

Each identified Zone 1 voltage stability limit includes a 5% security margin<sup>49</sup> to allow for real-time contingency management.

VSAT uses a 'sink and source' methodology to perform this modelling. The load in the upper North Island region acts as the sink and a selected group of North Island generators act as the source. Hydro and thermal generation types were chosen to be source generators as both types are more flexible for adjusting output. Geothermal and co-generation units are usually run at base-load and are less flexible for altering output. Wind turbines have weather-dependent generation profiles and are unsuitable for representing changes in output during the transfer analysis.

The VSAT model assumes loads in New Zealand are all constant (for both active and reactive power)<sup>50</sup>. This means the load megawatt and megavar values do not vary with voltage during the simulation.

## **A.4 VOLTAGE STABILITY SENSITIVITY ASSESSMENT**

Steady-state voltage stability analysis was repeated to examine the effectiveness of injecting active or reactive power at different bus locations to improve Zone 1 voltage stability limits. This is a high-level power system assessment of voltage stability sensitivity to compare options for alleviating Zone 1 voltage stability limits.

The observed changes in Zone 1 voltage stability limit were then calculated as an average ratio of per MW increase in the voltage stability limit to per positive MW or MVar injection at the corresponding North Island bus locations for each generation scenario, for summer and winter loads.

## **A.5 ZONE 1 PEAK LOAD FORECAST**

Table 11 has the published load forecast from Transpower's 2015 Transmission Planning Report, which shows the regional winter Island Expected Load Forecast for the upper North Island is 2200 MW. This aligned well with the actual 2015 peak load demand recorded for the region at 2150 MW.

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<sup>49</sup>A 5% voltage stability margin is included in both System Security Forecast studies and other voltage stability assessments.

<sup>50</sup> System Security Forecast studies adopts the same load modelling methodology.

*Table 11 Island Expected Load Forecast – Zone 1*

| Year | MW      |         | MVar   |        |
|------|---------|---------|--------|--------|
|      | Winter  | Summer  | Winter | Summer |
| 2015 | 2,202.8 | 1,706.9 | 242.2  | 290.7  |
| 2016 | 2,233.9 | 1,731.0 | 245.7  | 295.3  |
| 2017 | 2,252.7 | 1,741.5 | 247.7  | 297.2  |
| 2018 | 2,282.4 | 1,765.7 | 250.3  | 301.8  |
| 2019 | 2,313.0 | 1,790.9 | 253.7  | 306.5  |
| 2020 | 2,341.6 | 1,807.8 | 256.3  | 309.0  |

### A.5.1 Load assumptions

The regional expected winter and summer demand for the upper North Island published in the 2015 Transmission Planning Report was used to forecast active power growth in Zone 1. The reactive power forecast was derived from the observed power factor captured in a real-time SCADA snapshot for winter 2015.

Zone 1 Winter Island Expected Forecast 2016 was 2234 MW, power factor 0.991. Table 12 outlines the active and reactive power loads used in the studies.

*Table 12 Winter load assumptions*

| Period      | GOS Zone 1 |      | GOS Zone 2 |      | Total Zone 1 |      | Load Growth MW |
|-------------|------------|------|------------|------|--------------|------|----------------|
|             | MW         | MVar | MW         | MVar | MW           | MVar |                |
| Winter 2016 | 869        | 117  | 1365       | 184  | 2234         | 302  | 1.45%          |
| Winter 2017 | 876        | 118  | 1377       | 186  | 2253         | 304  | 0.85%          |
| Winter 2018 | 888        | 120  | 1395       | 188  | 2282         | 308  | 1.28%          |
| Winter 2019 | 900        | 122  | 1413       | 191  | 2313         | 312  | 1.36%          |
| Winter 2020 | 911        | 123  | 1431       | 193  | 2342         | 316  | 1.25%          |

The Zone 1 Summer Island Expected Forecast 2016/2017 was 1731 MW and power factor 0.983. Table 13 outlines the active and reactive power loads used in the studies.

*Table 13 Summer load assumptions*

| Period           | GOS Zone 1 |      | GOS Zone 2 |      | Total Zone 1 |      | Load Growth MW |
|------------------|------------|------|------------|------|--------------|------|----------------|
|                  | MW         | MVar | MW         | MVar | MW           | MVar |                |
| Summer 2016/2017 | 585        | 109  | 1146       | 214  | 1731         | 323  | 1.47%          |
| Summer 2017/2018 | 589        | 110  | 1154       | 215  | 1742         | 325  | 0.64%          |
| Summer 2018/2019 | 596        | 111  | 1170       | 218  | 1766         | 330  | 1.38%          |
| Summer 2019/2020 | 605        | 113  | 1185       | 221  | 1791         | 334  | 1.42%          |

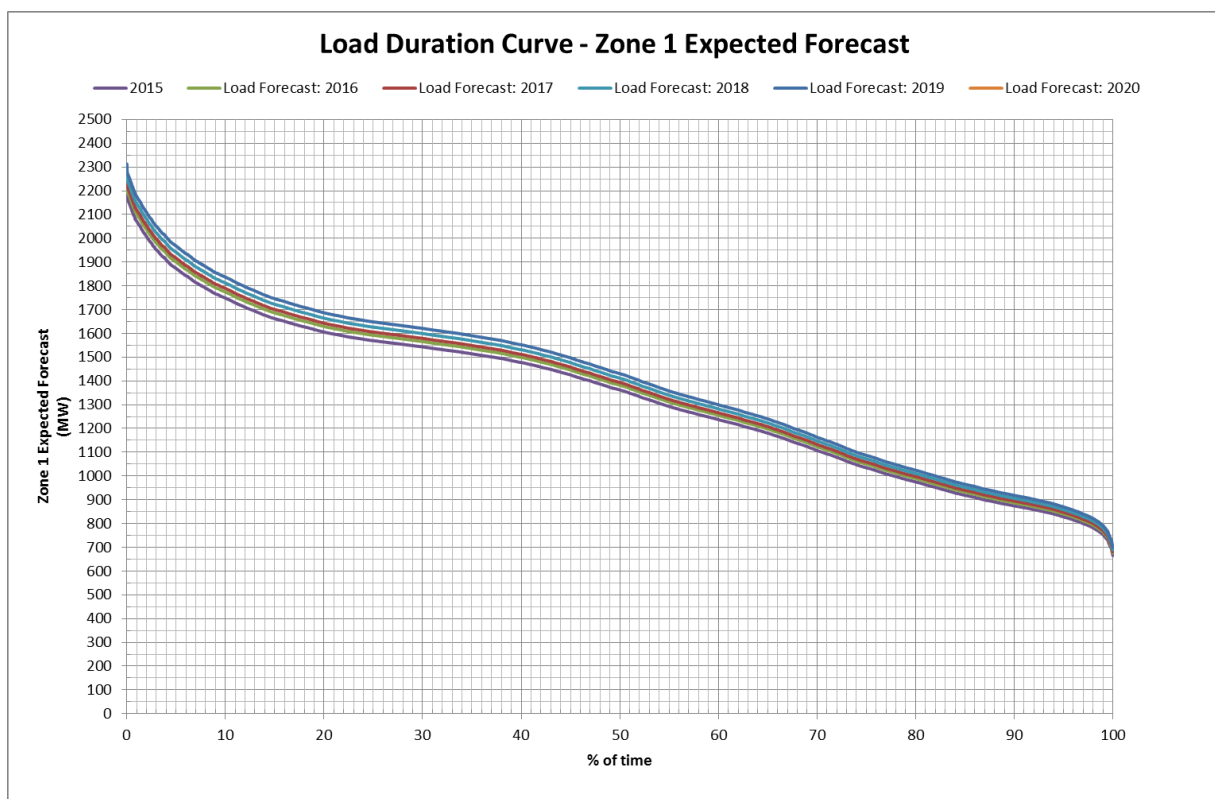
The Zone 1 Shoulder Island Expected Forecast 2016 was 1798 MW with power factor 0.983. Table 14 outlines the active and reactive power loads used in the studies.

Table 14 Shoulder load assumptions

| Period        | GOS Zone 1 |      | GOS Zone 2 |      | Total Zone 1 |      | Load Growth MW |
|---------------|------------|------|------------|------|--------------|------|----------------|
|               | MW         | MVAr | MW         | MVAr | MW           | MVAr |                |
| Shoulder 2017 | 608        | 113  | 1190       | 222  | 1798         | 336  | 1.01%          |
| Shoulder 2018 | 620        | 116  | 1214       | 226  | 1833         | 342  | 1.02%          |
| Shoulder 2019 | 626        | 117  | 1228       | 229  | 1854         | 346  | 1.01%          |
| Shoulder 2020 | 633        | 118  | 1241       | 231  | 1875         | 350  | 1.01%          |

Figure 1 shows the Load Duration Curve of Zone 1 Expected Load Forecast. The seasonal Zone 1 Expected Load Forecast<sup>51</sup> and load duration curves (LDC)<sup>52</sup> were used in this study as a reference for the identified thermal overload and voltage stability limits.

Figure 1 Load Duration Curve – Zone 1 Expected Forecast



## A.6 STUDY ASSUMPTIONS

Unless specified for individual study scenarios, the following assumptions were applied in this study.

<sup>51</sup> The Seasonal Zone 1 Expected Load Forecast is derived from separating the scaled metered 2015 Zone 1 load demand into summer/shoulder/winter, as defined in Section A.3.

<sup>52</sup> The Seasonal Load Duration Curves of Zone 1 Expected Forecast was derived from the scaled metered 2015 Zone 1 load demand data extrapolated to reflect the seasonal Zone 1 Island Expected Load Forecast and growth rate (averaging 1.24% for winter, 1.22% for summer and 1.32% for shoulder, year on year growth).



### A.6.1 Seasons studied

Transpower's planning definitions of summer, shoulder and winter are:

- Summer: 1st December – 15th March
- Shoulder: 15th March – 10th May, 20th October – 1st December
- Winter: 10th May – 20th October

### A.6.2 Contingency and outage scenarios

The studies considered three contingency scenarios:

N-1 condition: one transmission contingent event, eg the loss of a single circuit, reactive source, or generator. The full database of N-1 contingencies defined in STCA and "VSAT Zone 1" was tested. The most severe/limiting contingency identified was combined to produce additional contingency definitions for assessing in the N-G-1 and N-1-1 outage scenarios.

N-G-1 condition: outage of Huntly Unit 5, which represents the worst case single generator outage scenarios for Zone 1 power transfer.

N-1-1 condition: outage of Pakuranga-Whakamaru-1 or 2 220 kV circuit, which represents the worst case single circuit outage scenario for Zone 1 power transfer.

STCA screened a full database of contingencies defined for the North Island power system.

VSAT screened a full database of contingencies defined for the upper North Island power system.

### A.6.3 Network assumptions

The following network assumptions were used:

- All SVC and STATCOMs available and in service
- All Zone 1 capacitors available and in service
- Sufficient hydrology in South Island for high HVDC transfer<sup>53</sup>; 700 MW in the summer and 1000 MW in the winter (maximum transfer capability of 900 MW in summer and 1200 MW in winter is assumed for the voltage stability sensitivity analysis).
- System slack bus at Stratford 220 kV bus. Slack bus is kept within stated capability at all times.
- Hangatiki-Te Awamutu 110 kV line in service from June 2016 (committed grid upgrade)
- Arapuni bus split open (normal state)
- Penrose reactor bypassed (normal state)

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<sup>53</sup> Reserve requirement of covering a HVDC contingent or extended contingent event presents a separate system issue and was not examined in these studies.

- New system split at Bunnythorpe-Mataroa-1 (this removes a limiting issue identified in a previous study<sup>54</sup>).

#### A.6.3.1 Voltage profile

Application of specific seasonal voltage profiles were captured through extraction of real-time SCADA system snapshots. Table 15 gives an indication of key bus voltages in the Zone 1 region for the winter period.

*Table 15 Zone 1 key bus voltages*

| 220 kV Bus Name | Summer Voltage (Per unit) | Winter Voltage (Per unit) |
|-----------------|---------------------------|---------------------------|
| Albany          | 1.050                     | 1.045                     |
| Henderson       | 1.048                     | 1.046                     |
| Otahuhu         | 1.046                     | 1.041                     |
| Penrose         | 1.048                     | 1.044                     |

#### A.6.3.2 Transformer tap changers

All 220/110 kV interconnecting transformers in the Zone 1 region are on-load tap changing transformers except for Otahuhu T2. For the analysis, auto-voltage regulation mode was 'switched' to manual for all interconnectors in the region and an indicative tap changer position set for individual transformers as shown in Table 16. Transformer tap position was adjusted pre-contingency if low voltage was observed during the analysis and locked during contingency simulation.

*Table 16 Zone 1 interconnecting transformer tap positions*

| 220/110 kV Interconnecting Transformer | High voltage tap changer position |
|----------------------------------------|-----------------------------------|
| Albany T4                              | 5                                 |
| Henderson T1                           | 5                                 |
| Henderson T5                           | 5                                 |
| Otahuhu T2                             | 1                                 |
| Otahuhu T3                             | 6                                 |
| Otahuhu T4                             | 5                                 |
| Otahuhu T5                             | 6                                 |
| Penrose T6                             | 9                                 |
| Penrose T10                            | 5                                 |
| Marsden T5                             | 9                                 |
| Marsden T6                             | 10                                |

<sup>54</sup> The full report is published on the System Operator website or click here for "[Upper North Island Supply Study - Managing Peak Loads Following Southdown and Otahuhu Retirements \(updated 3rd Nov 2015\)](#)" Page 4".

Transformer tapping to maintain low voltage buses can have an impact on high voltage bus voltages. Where required, distribution transformers were tapped to maintain low voltage bus voltages within normal operational band.

### A.6.3.3 Reactive plant

All Transpower controlled North Island capacitors were assumed to be available and switched-in service<sup>55</sup>. Table 17 gives the reactive capability of the capacitors in the Zone 1 region.

*Table 17 Zone 1 static reactive support*

| Reactive Plant                       | Voltage (kV) | Export Capability |
|--------------------------------------|--------------|-------------------|
| Albany<br>C1<br>C2                   | 110<br>220   | 50<br>100         |
| Bombay C11                           | 110          | 50                |
| Henderson C1                         | 220          | 75                |
| Hepburn Road C11, C12, C13           | 110          | 3 x 50            |
| Kaikohe*<br>C1, C2, C3, C4           | 11           | 20                |
| Kaitaia*<br>C1 binary cap            | 33           | 24                |
| Otahuhu<br>C29, C30, C31<br>C11, C12 | 220<br>110   | 3 x 100<br>2 x 50 |
| Penrose<br>C1<br>C11, C12, C13, C14  | 220<br>110   | 75<br>4 x 50      |
| Wairau Road C1, C2                   | 33           | 2 x 18            |

\*Operational control has been transferred to TOP Energy from 09/2015.

All dynamic reactive support was assumed to be available with import and export capability maintained. Table 18 gives the reactive capability of the SVC's and STATCOM's in Zone 1.

*Table 18 Zone 1 dynamic reactive support*

| Reactive Plant    | Import Capability | Export Capability |
|-------------------|-------------------|-------------------|
| Albany SVC        | -100              | 100               |
| Marsden STATCOM 5 | -34               | 40                |
| Marsden STATCOM 6 | -34               | 40                |
| Penrose STATCOM   | -60               | 60                |

<sup>55</sup> From September 2015, operational control of Kaitaia 110 kV capacitors does not reside with Transpower. For prudent power system assessment the reactive power injection from the Kaitaia 110 kV capacitors was assumed at 0 MVar in the base-case.

#### A.6.4 Generation and HVDC dispatch assumptions

A realistic mix of generation and units operating was important to ensure study cases captured correct network and operating conditions. Table 19 lists the capacity and assumed dispatch of the generation in the upper North Island region.

*Table 19 Upper North Island generation assumption*

| Generation                             | Capacity | Dispatch | Comments                             |
|----------------------------------------|----------|----------|--------------------------------------|
| Otahuhu CCGT                           | 380 MW   | 0 MW     | Decommissioned from 30 Sep 2015      |
| Southdown                              | 140 MW   | 0 MW     | Decommissioned from 1 Jan 2016       |
| Glenbrook                              | 112 MW   | 68 MW    | In service                           |
| Ngawha                                 | 25 MW    | 22 MW    | In service                           |
| Huntly<br>Coal (Rankine units 3 and 4) | 500 MW   | 0 MW     | Decommissioned Nov 2014 and Jun 2015 |
| Coal (Rankine units 1 and 2)           | 500 MW   | 500 MW   | Decommissioned from Dec 2018         |
| CCGT (unit 5)                          | 400 MW   | 400 MW   | In service                           |
| GT (unit 6)                            | 50 MW    | 50 MW    | In service                           |
| Te Uku                                 | 64 MW    | 0 MW     | Out of service <sup>56</sup>         |
| Te Rapa                                | 44 MW    | 40 MW    | In service                           |

System snapshots from SCADA were used to provide realistic generation dispatch combinations. Megawatts of specific generation types were altered to construct the three generation scenarios described in Section 3.1 and 3.2.

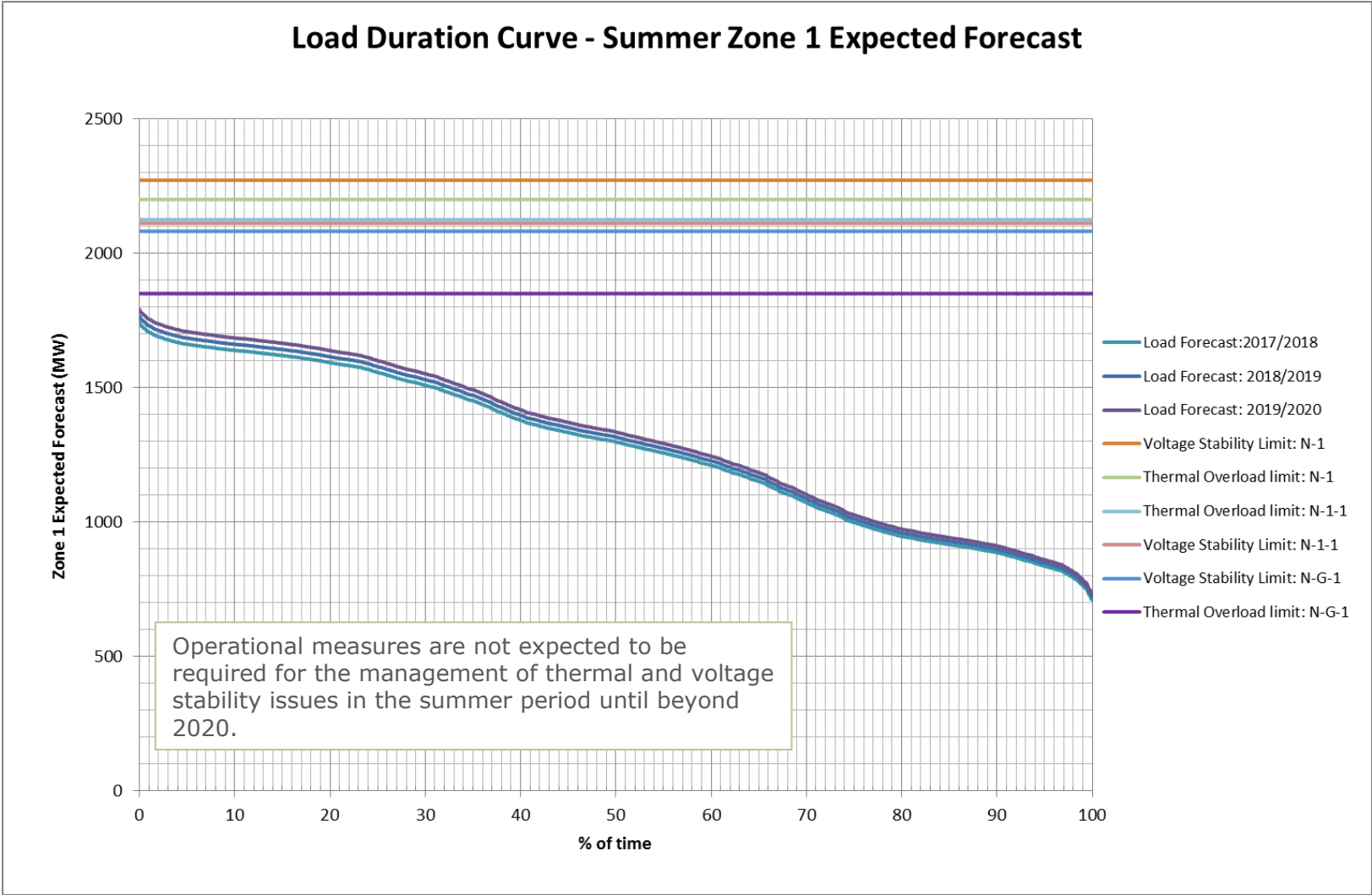
For study cases where additional generation was required to balance Zone 1 load, the shortfall was compensated for by increasing North Island thermal generation output and transfer across the HVDC link to their maximum capability.

<sup>56</sup> For Zone 1 voltage stability assessment Te Uku wind generation was assumed out of service in the restricted generation scenario. See Section 3.1 and 3.2 for more details.

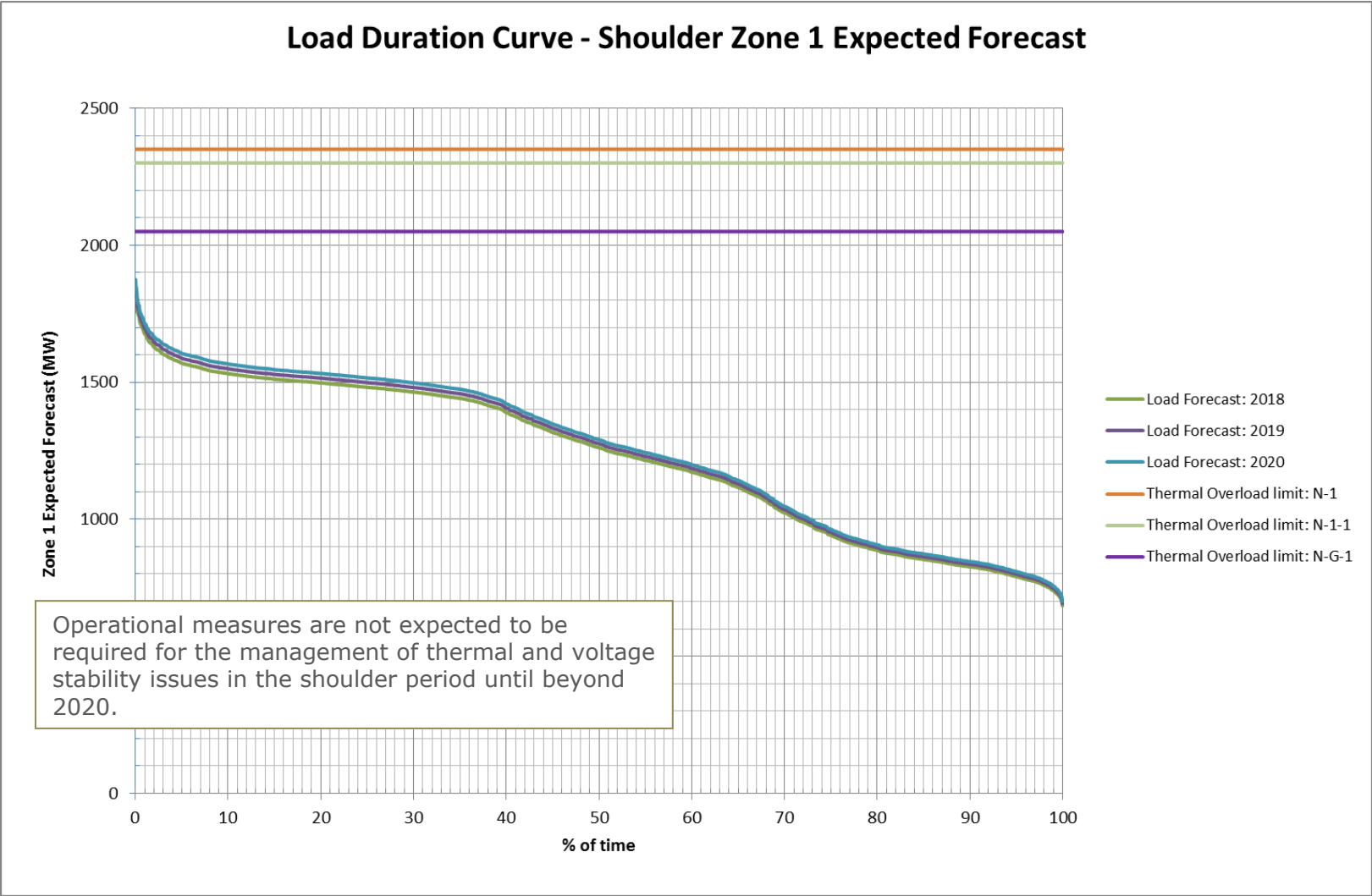
## **Appendix B:      ANALYSIS RESULTS PLOTTED AGAINST FORECAST LOAD DURATION CURVES**

This section presents the thermal overload and voltage stability limits superimposed on seasonal load duration curves, to provide an indication on the year and proportion of time the load forecast is expected to exceed these identified limits.

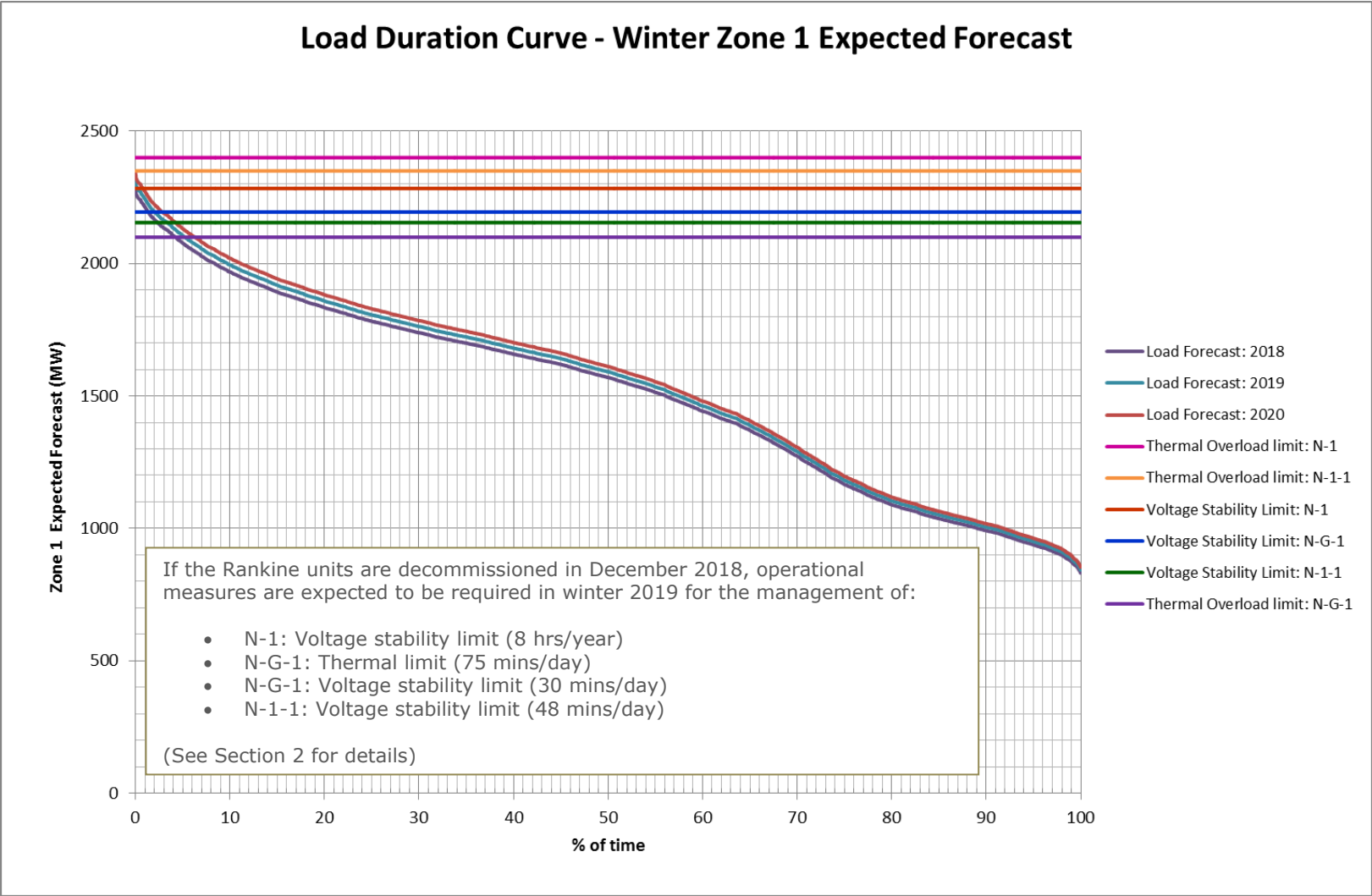
B.1 SUMMER ZONE 1 EXPECTED FORECAST



**B.2 SHOULDER ZONE 1 EXPECTED FORECAST**



**B.3 WINTER ZONE 1 EXPECTED FORECAST**





## Appendix C: OPERATIONAL MEASURES

Transpower uses a range of measures in planning and real time system operations to manage constraints and events on the power system. This section discusses operational measures which could be utilised for managing identified Zone 1 thermal and voltage stability limits.

### C.1 CUSTOMER AGREEMENTS AND CONSTRAINT EQUATIONS

34

Reliance on load management and generation dispatch agreements and use of equation (market node and permanent) constraints is a 'no investment in physical assets' option useable by Transpower for managing both thermal and voltage stability limits under normal and outage operating conditions.

Agreements for load management and generation offering and formulation of thermal or voltage stability constraint equations for different network and grid configurations are considered and arranged in normal operational planning time-frames.

### C.2 ANCILLARY SERVICE CONTRACT FOR VOLTAGE SUPPORT

As system operator, Transpower is responsible for understanding how certain conditions impact operation of the power system (from a short term perspective) and taking appropriate actions to manage conditions to ensure Transpower meets the PPOs. One available action is to procure ancillary services, such as voltage support.

Transpower procures ancillary services on behalf of the industry. To ensure procurement is reasonable, prudent and cost-effective, Transpower follows the procurement methodology and mechanism in the Procurement Plan. These processes require an assessment be made of the quantity of services required to enable compliance with the PPOs.

### C.3 VARIABLE LINE RATINGS

Since November 2011 Transpower has trialed variable line ratings on six circuits as shown in Table 20. These maximize capacity of these circuits, reducing the likelihood of an N-1 thermal constraint (on these circuits) under certain grid configuration and generation scenarios. The thermal limits in this study took into account the increased capacity of the six circuits.

*Table 20 Variable Line rating circuit names*

| Circuit                         |
|---------------------------------|
| Otahuhu-Whakamaru-1 (OTA-WKM-1) |
| Otahuhu-Whakamaru-2 (OTA-WKM-2) |
| Atiamuri-Ohakuri-1 (ATI-OHK)    |
| Ohakuri-Wairakei-1 (OHK-WRK)    |
| Bombay-Otahuhu 1 (BOB-OTA-1)    |

**Circuit**

Bombay–Otahuhu 2 (BOB-OTA-2)

The inclusion of additional specific circuits into Transpower’s variable line rating scheme may serve to increase thermal limits into Zone 1.

The thermal capacity and voltage stability assessments examined the existing North Island transmission network and did not consider inclusion of additional circuits into the variable line rating scheme. If the thermal capacity of circuits identified in Section 2.2 is increased using variable line rating, it is likely to improve Zone 1 thermal limit, but have no impact on lifting the voltage stability limits.

## C.4 DEMAND RESPONSE

35

Transpower has been trialing a commercial Demand Response program, a transmission investment deferment product used to manage load demand during the testing phase of the HVDC Pole 3 project and an outage of Tekapo A power station. An estimated 214 MW of upper North Island load can participate in this program.

The thermal capacity and voltage stability assessments examined the existing North Island transmission network and did not consider the impacts available from the Demand Response program.

If operational agreements and commercial arrangements can be made to facilitate the operational utilisation of Demand Response, it could be used by the System Operator as an alternative load management option.

## C.5 LOWERING DISTRIBUTION BUS VOLTAGE SET-POINT

The 2013 Transpower Upper North Island Voltage Stability – Information Collation load survey<sup>57</sup> indicated that the percentage of voltage-dependent loads in Zone 1 is approximately 52.7% in winter and 39.3% in summer. By lowering distribution bus voltage set-points voltage-dependent loads could be expected to decrease their power consumption proportionally to the drop in voltage set-point.

Voltage stability assessment studies have shown Zone 1 voltage stability limits improve if voltage-dependent loads were considered in the load modeling<sup>58</sup>. However, the precise behavior of loads needs to be further analysed before any modeling change is made to Transpower’s operational tools. Changes to these tools to assist management of voltage stability or thermal limits are unlikely within the 3 year timeframe of this study.

<sup>57</sup> Transpower’s internal investigation report providing informed estimates at grid-exit points of static loads, motor loads and power factor correction in the upper North Island region.

<sup>58</sup> Currently, Zone 1 loads are modelled as constant power loads and are not sensitive to voltage deviation. Improvement is observed by changing the modelling of loads to voltage sensitive constant impedance loads.

## **Appendix B: Transpower's 18 May 2016 observations on the impact of retaining the Rankine units on the operation of the power system**

### **Introduction**

Over 2015 and 2016 Transpower has been undertaking analyses to determine what the impact of the decommissioning of Otahuhu Power Station, Southdown Power Station and the last 2 Rankine generating units at Huntly Power Station will have on network conditions, operation of the power system, security of supply and the need for grid investment. Reports have been produced to help inform the electricity industry of the potential implications of planned and recent generation plant closures.

Since the last update to the SRC regarding the operational and security of supply impacts of the thermal generation decommissioning, Transpower has published the "Upper North Island Operational Limits" report.

A copy of this report is attached [as Appendix A]. The report was published before Genesis' announcement that the Rankine units were being retained until 2022.

This [appendix B] summarises the findings, and provides an update on what retention of the Rankine units until 2022 has on the operation of the grid, grid investment, and security of supply.

### **Impact of Retaining Rankine Units on Operation of the Power System**

#### **Upper North Island Operational Limits**

Transpower released the report "Upper North Island Operation Limits" in April 2016. This report details the thermal and voltage stability load limit into Auckland and Northland with and without the Rankine units until 2020. It also identified where additional reactive support could have the greatest impact on upper North Island voltage stability limits.

If the Huntly Rankine units were decommissioned in 2018, the upper North Island power system will be more susceptible to risk exposures from high peak loads and extended or unplanned outages of assets such as generators, circuits or reactive support equipment. Identified thermal capacity and voltage stability issues can be managed satisfactorily with all transmission and generation assets currently in service and available to the market in 2018, however there is a risk of load management at peak times in winter 2019 and 2020 and also during contingency and outage conditions.

Transpower's studies highlight the power system's dependence on the availability of key assets in the winter period, namely, the remaining generation at Huntly and transmission assets, to meet forecast upper North Island peak demand.

The report makes reference to earlier security of supply analysis, which found the ability to meet peak load in the North Island is at risk if little generation was built and the Huntly Rankine units are decommissioned by the end of 2018. Load management may be required in some circumstances to manage the entire North Island power system, including the upper North Island. Previously, when this type of load management was forecast, industry and regional forums were established by Transpower to assist determining optimised or preferred solutions to manage peak winter loads including voltage support contracts and demand side management. The need for such an approach for the upper North Island in 2019 and 2020 would be reviewed in the context of any wider North Island peak capacity issues.

### **Conclusion**

The retention of the Rankine units by the market for a further four years alleviates the situations identified from 2019 onwards when it could have been difficult to meet New Zealand's electricity needs had the Rankine units closed and not been replaced by any new generation sources. The expected forecast demand can be met, assuming all assets in service and with normal market constraints in dispatch, until the Rankine units are decommissioned.

### **Impact of Retaining Rankine Units on Grid Investment Analysis Work Programme**

Transpower released the report "Upper North Island generation decommissioning report: summary of investigations Stage 1" in mid-March 2016. This report detailed the six work streams investigating grid investment needs resulting from the retirement and proposed retirement of approximately 1000MW of thermal generation since 2015.

The analysis showed that voltage concerns in the upper North Island are common to the majority of scenarios regarding generation retirement and future generation investment. At the time of publication Transpower announced it was undertaking an investigation into investment options to resolve the voltage issues identified in the report.

Since the report publication Transpower has continued to refine its analysis of the voltage issues, in particular extending the region of analysis to include Waikato. This has shown that the need date for investment in dynamic voltage support in the wider region is brought forward by approximately 3 -4 years.

### **Conclusion**

The retention of the Rankine units by the market for a further four years has changed the need date for investment in voltage support, but not by the full four years. The extent of the voltage support required is sufficiently high that with the Rankine units in service dynamic voltage issues are forecast earlier than 2022. Transpower are currently revising the load forecast and will update the industry with any change to the required investment date.

Given the analysis, approval and build time for transmission assets, Genesis's announcement does not mean that the investigation can be deferred. Rather, it means there should now be just enough time to deliver to meet the need. In winter 2016, a request for information (RFI) on non-transmission solutions is planned, including issuing a long list of possible grid investment options and call for feedback on the generation and demand growth assumptions used. Transpower looks forward to the industry's view on these.

### **Impact of Retaining Rankine Units on Security of Supply**

Transpower released the report "Security of Supply Analysis of Thermal Decommissioning" in December 2015, and the 2016 Security of Supply Annual Assessment in February 2016. These reports focused on understanding the Security of Supply implications in the next 5-10 years, taking into account the decommissioning of Otahuhu B, Southdown and Huntly Rankine units.

Analysis showed that if no new generation was built prior to Rankine unit decommissioning the security of supply risk will be very high, and the power system will potentially be exposed to energy shortages in dry conditions. This risk was significantly reduced in scenarios where new generation was built.

***Conclusion***

The retention of the Rankine units by the market for a further four years has significantly reduced the security of supply risk.