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<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
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**IMPORTANT**

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1. **EXECUTIVE SUMMARY**

The purpose of this study is to assess any voltage stability (VS) issues that may arise from low generation scenarios in the Upper North Island (UNI or Zone 1) area in the winter from May 2015 to September 2015 inclusive.

Voltage stability is primarily affected, in Zone 1, when one of the bigger generating plants has tripped and the load is high. This limiting contingent plant is usually at Otahuhu B or Huntly.

The following scenarios were studied for low Zone 1 generation, during peak load periods to identify the corresponding load limit. These scenarios represent ‘reasonable’ and a ‘worst case’ system conditions under which to assess voltage stability in the region.

**Table 1: Zone 1 load limits**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Huntly Units 1, 2 or 4</th>
<th>Huntly Unit 5</th>
<th>Otahuhu B</th>
<th>Limiting Contingency</th>
<th>Expected Forecast Load</th>
<th>VS Load Limit</th>
<th>Margin MW</th>
<th>Margin %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IN</td>
<td>IN</td>
<td>OUT</td>
<td>Huntly U5</td>
<td>2162</td>
<td>2580</td>
<td>418</td>
<td>19.33</td>
</tr>
<tr>
<td>2</td>
<td>IN</td>
<td>OUT</td>
<td>OUT</td>
<td>Huntly U2</td>
<td>2162</td>
<td>2465</td>
<td>303</td>
<td>14.01</td>
</tr>
</tbody>
</table>

The results of the studies show that the UNI peak winter demand can be met with all available plant in service as there is adequate margin (>5%) even in the worst case scenario 2 above.

Therefore, there are no requirements this winter for:

- A NIWA report to assess expected extreme weather conditions with accompanying high Zone 1 loads
- An UNI Contingency plan whereby Auckland load is managed pre or post contingently to mitigate potential voltage collapse when the contingent plant trips
2. **INTRODUCTION**

The purpose of this document is to provide market participants with an indication of what the limiting load limits are for the UNI based on historic low Zone 1 generation scenarios. The limiting contingent loss of plant causing voltage collapse in Zone 1 is generally a generator as opposed to a transmission line. This study cannot be used to infer system transfer limits at a glance but will give indicative load limits based on these generation scenarios. In real time VS is managed based on system conditions at the time.

2.1 **UPPER NORTH ISLAND NETWORK OVERVIEW**

The UNI is the area that encompasses Grid Zones 1 and 2, also known as Zone 1, including the Auckland and Northland regions. The region is supplied by eight 220 kV and three 110 kV transmission circuits from the south. The 220 kV circuits originate from Huntly, Ohinewai, and Whakamaru buses. The 110 kV circuits originate from the Arapuni and Hamilton buses in the Waikato region.

Capacitor banks are available at Albany, Bombay, Henderson, Hepburn Road, Kaikohe, Kaitaia, Otahuhu and Penrose substations. A Static Var compensator (SVC) is installed at Albany and STATCOMS are installed at Penrose and Marsden substations.

The UNI region is shown geographically in Figure 1.
Figure 1: Geographic Representation of Upper North Island
2.2 **Upper North Island Schematic Overview**

![Schematic Representation of the Transmission network of Upper North Island](image)

*Figure 2: Schematic Representation of the Transmission network of Upper North Island*
3. Assumptions & Methodology

The following assumptions and methodology are applied in the assessment of voltage stability in the UNI.

3.1 Grid Configuration

It is assumed that there are no transmission outages unless otherwise stated. There are 11 circuits supplying the Auckland region and a single outage of one of these circuits essentially has little effect on voltage stability. There is also significant local generation.

3.2 Generation Scenarios

Maintenance is generally not carried out on generators in winter so the following generation scenarios are used for the study. These scenarios represent ‘reasonable’ and a ‘worst case’ system conditions under which to assess voltage stability in the region.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2 x Huntly Units from 1, 2 &amp; 4</th>
<th>Huntly Unit 5</th>
<th>Otahuhu B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IN</td>
<td>IN</td>
<td>OUT</td>
</tr>
<tr>
<td>2</td>
<td>IN</td>
<td>OUT</td>
<td>OUT</td>
</tr>
</tbody>
</table>

Table 2: Generation Scenarios

<table>
<thead>
<tr>
<th>Plant</th>
<th>Rating (MW)</th>
<th>Rating (Mvar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huntly Units 1, 2 and 4</td>
<td>250</td>
<td>-53 / 162</td>
</tr>
<tr>
<td>Huntly Unit 5</td>
<td>380</td>
<td>-216 / 245</td>
</tr>
<tr>
<td>Otahuhu B</td>
<td>380</td>
<td>-195 / 275</td>
</tr>
</tbody>
</table>

Table 3: Generation Ratings
3.3 Other Generation Assumptions

The following are assumed values for other generating stations. These are typical historical values for a low generation scenario.

Table 4: Other Generation Assumptions

<table>
<thead>
<tr>
<th>Station</th>
<th>Generation (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southdown</td>
<td>140</td>
</tr>
<tr>
<td>Glenbrook</td>
<td>55</td>
</tr>
<tr>
<td>Ngawha</td>
<td>24</td>
</tr>
<tr>
<td>Waikato Block</td>
<td>600</td>
</tr>
</tbody>
</table>

3.4 Dynamic Reactive Plant Capability

The following dynamic reactive plant are used in Zone 1

Table 5: Dynamic Reactive Plant Status

<table>
<thead>
<tr>
<th>Plant</th>
<th>Rating (Mvar)</th>
<th>Scenario 1 &amp; 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany SVC</td>
<td>-100/+100</td>
<td>IN</td>
</tr>
<tr>
<td>Penrose Statcoms</td>
<td>2 x -30/+30</td>
<td>IN</td>
</tr>
<tr>
<td>Marsden Statcoms</td>
<td>2 x -34/+40</td>
<td>IN</td>
</tr>
</tbody>
</table>
3.5 Load Forecast

Loads used in this study are based on a morning peak scenario. These load values were provided by the lines companies.

<table>
<thead>
<tr>
<th></th>
<th>2014 Actual Peak (MW)</th>
<th>2015 Expected Forecast Peak (MW)</th>
<th>Growth from 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counties Power</td>
<td>110.5</td>
<td>117</td>
<td>5.9%</td>
</tr>
<tr>
<td>Northpower</td>
<td>170</td>
<td>170</td>
<td>0.0%</td>
</tr>
<tr>
<td>NZ Steel</td>
<td>102</td>
<td>90</td>
<td>-11.8%</td>
</tr>
<tr>
<td>Top Energy</td>
<td>58.1</td>
<td>58.9</td>
<td>1.4%</td>
</tr>
<tr>
<td><strong>Total Zone 1</strong></td>
<td><strong>2160.6</strong></td>
<td><strong>2162.1</strong></td>
<td><strong>0.1%</strong></td>
</tr>
</tbody>
</table>

Zone 1 peak power factor = 0.99. This is the worst case value for the last year.

3.5.1 Definitions

**Expected forecast Peak**
this forecast is the peak demand that each lines company would expect to see in the average winter, MW

**Actual Peak**
this is the actual system peak demand from SCADA, MW

**Margin**
difference between Actual and expected load, %

3.6 General Methodology

Voltage stability studies are carried out for each scenario using the expected 2015 load. The study is iterated by scaling up the load until the voltage collapse point is reached. The load limit is then determined as being 95% of the voltage collapse point. This value represents the highest load that can be attained in Zone 1, for that particular scenario, before any load management is required.

1 The NZ Steel load is the actual offtake from the network which is gross load less their generation. The lower value is due to improved energy plant efficiencies and load management.
4. RESULTS

4.1 RESULTS VOLTAGE STABILITY

The table below shows load limits and the respective margins available for the scenario studied.

Table 7: Generation Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Huntly Units 1, 2 or 4</th>
<th>Huntly Unit 5</th>
<th>Otahuhu B</th>
<th>Limiting Contingency</th>
<th>Expected Forecast Load</th>
<th>VS Load Limit</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IN</td>
<td>IN</td>
<td>OUT</td>
<td>Huntly U5</td>
<td>2162</td>
<td>2580</td>
<td>418</td>
</tr>
<tr>
<td>2</td>
<td>IN</td>
<td>OUT</td>
<td>OUT</td>
<td>Huntly U2</td>
<td>2162</td>
<td>2465</td>
<td>303</td>
</tr>
</tbody>
</table>

In the above scenarios the expected 2015 forecast load of 2162 MW can be met adequately without any load management mitigation.

A margin over 5% or 108 MW is considered adequate for the UNI to allow for variations due to adverse weather conditions and concurrent single transmission outages.
5. **APPLICATION OF LOAD LIMIT**

5.1 **CONSTRAINTS**

The load limit is enforced in the forward looking schedules and in real-time using market stability constraints.

The stability constraint is applied normally using an equation with a high RHS (default value). The high RHS value is used to allow for variations in power factor, load, generation and reactive support. In real-time the RHS is adjusted to match system conditions at the time.

The constraint used is

**Constraint Name:** UPPER_NORTH_ISLAND_STABILITY_P_1C

**Constraint Equation:**

\[
1 \times \text{HLY
dry_OTA2.1} + -1 \times \text{DRY_HLY1.1} + 1 \times \text{OHW
dry_OTA1.1} + 1 \times \text{OHW
dry_OTA2.1} + -1 \times \text{OTA_WKM1.1} + -1 \times \text{OTA_WKM2.1} + -1 \times \text{PAK_WKM1.1} + -1 \times \text{PAK_WKM2.2} + -1 \times \text{BOB_HAM1.1} + -1 \times \text{BOB_HAM2.1} + 1 \times \text{ARI_BOB1.1} \leq \text{RHS}
\]

The following table shows the indicative RHS that could be applicable for the scenarios studied.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>VS Eqn. RHS (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Default value</td>
<td>2500</td>
</tr>
<tr>
<td>1</td>
<td>2455</td>
</tr>
<tr>
<td>2</td>
<td>2335</td>
</tr>
</tbody>
</table>

Note: RHS is the transfer into the region (zone) and not the load limit
6. **Summary**

The results indicate that the expected 2015 forecast can be met with adequate voltage stability margins in the UNI. Therefore, there are no requirements this winter for:

- A NIWA report to assess expected extreme weather conditions with accompanying high Zone 1 loads
- An UNI Contingency plan whereby Auckland load is managed pre or post contingently to mitigate potential voltage collapse when the contingent plant trips

If system conditions significantly change during winter such as:

- Unexpected outages on generators
- Unexpected outages on transmission plant
- Unexpected higher loads

Then new studies will be carried out and the industry notified accordingly.
7. **APPENDIX**

7.1 **REVIEW LAST WINTER**

The actual peak last year was below the expected forecast load 2297 MW as shown in the bar chart below.

**Figure 3: Last Winter Review**

Upper North Island winter peak 2014 demand was supplied without any system security issues.

**Figure 4: Comparison of Previous Years Load**

Upper North Island winter peak 2014 demand was supplied without any system security issues.