ABN: 77 086 347 300

Tuesday, 25 July 2006

Report to:

# *Export Capability of Proposed Uranquinty Power Station*

| | |
|---|---|
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## Executive Summary

Wambo Power Ventures proposes to construct a power station at Uranquinty located near Wagga in southern New South Wales. The power station will consist of four (4) 150MW gas turbine generators each with its own 190MVA 15.75/132kV step-up transformer. The proposal includes the construction of a switching station at Uranquinty and the reconstruction of existing 132kV transmission lines between Uranquinty and TransGrid's Wagga 330kV substation.

The objective of this study is to ascertain the ability of the generators to export power into Transgrid's 330kV southern New South Wales network. The proposed Uranquinty power station will be in competition with NSW generation for 330kV transmission capacity. The power station will also be in competition with Snowy Mountain's and Victorian generators at different times throughout the year. This report outlines the effect the Uranquinty power station will have on existing power transfer limits on the 330kV transmission network.

A generation scheduling exercise was conducted to determine the times at which Uranquinty would generate based on the market price exceeding $50/kWh. The results found that Uranquinty would be online for approximately 5% of the year with a total generation of around 240GWh,The study also determined that there would be no significant restrictions imposed by transfer limits of the existing 330kV transmission system. The studies covered the years 2008, 2013, and 2018

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# 1. Introduction

Wambo Power Ventures proposes to construct a power station at Uranquinty located in southern New South Wales. The power station will consist of four (4) nominally 150MW gas turbine generators each with its own 190MVA 15.75/132kV step-up transformer. The proposal includes the construction of a switching station located at Uranquinty and the reconstruction of existing 132kV transmission lines between Uranquinty and TransGrid's Wagga 330kV substation. The sequence of works comprising the grid connection, is outlined in Appendix B.

This report outlines the capability of the Uranquinty Power Station to export power into the Transgrid 330kV system in the southern New South Wales region. The proposed Uranquinty Power Station will be in competition with NSW generation for 330kV transmission capacity. The power station will also be in competition with Snowy Mountain's and Victorian generators at different times throughout the year.. Both thermal and stability limits will have to be considered. This report outlines the effect the Uranquinty power station will have on any existing power transfer limits on the 330kV network.
The main aims of the investigations are:

1. Establish the conditions under which any restrictions may apply to export from Uranquinty into the 330kV system.
1. The extent of any restriction.
2. The probability of any restriction.

# 2. Scope

## 2.1. Generation Scheduling

Generation scheduling simulations were run to estimate under what conditions the Uranquinty Power Station will be operating and with which power stations it might be competing for transmission capacity.

HMAC engaged ROAM Consulting to undertake the generation scheduling simulations using its 2-4-C market forecasting package. 2-4-C generates its forecasts of the market on the basis of rigorous modeling of the probable operation of the market.

A description of the program and modelling techniques can be found in Appendix D. Wambo Power estimates that the Uranquinty sets would generate at times when the generating price exceeds $50/MWh.

When power transfer limits are reached between Snowy and NSW and between Snowy and Victoria, Uranquinty will compete with Snowy generation. Because Snowy can always bid to use its water storage, the generation simulations indicate that generation restrictions at Uranquinty, when bidding at $50/MWh, do not occur. However there could be some loss of revenue to Snowy through having to bid at lower prices to use its water.

The transfer limit between Snowy and NSW was varied to gauge the competition for generation between the proposed Uranquinty Power Station and the Snowy region.

## 2.2. Load Flow Studies

Following the generation scheduling simulations, load flow studies were carried out to determine whether or not there are any potential overloads on the system. These load flows also determine any conditions under which generation out of Uranquinty will need to be constrained and by how much.

## 2.3. Stability Studies

To determine if stability is a factor in limiting output from Uranquinty and to determine the limiting level of generation, studies were undertaken using typical power flow results established from the load flow studies as base cases.

# 3. System Data

## 3.1. Generation Scheduling

The generation scheduling process was undertaken by ROAM Consulting using their 2-4-C market forecasting package. A description of the model can be found in Appendix D.

## 3.2. Load Flow Studies

Load flow studies were performed to determine the limit of the Uranquinty generators whilst under steady state conditions and abnormal or line-out conditions. The results from the generation scheduling process were then used to ascertain overloads in relevant 132kV and 330kV transmission lines under steady state and line out conditions.

## 3.3. Stability Studies

PSS/E was used to model the network with data obtained from NEMMCO. The 5 NEMMCO snapshots were used to determine the stability limit of the Uranquinty generators. For high power transfer from Snowy to NSW the High Winter snapshot was used, whilst the High Mid-Season snapshot was used for high power transfer from Snowy to Victoria.

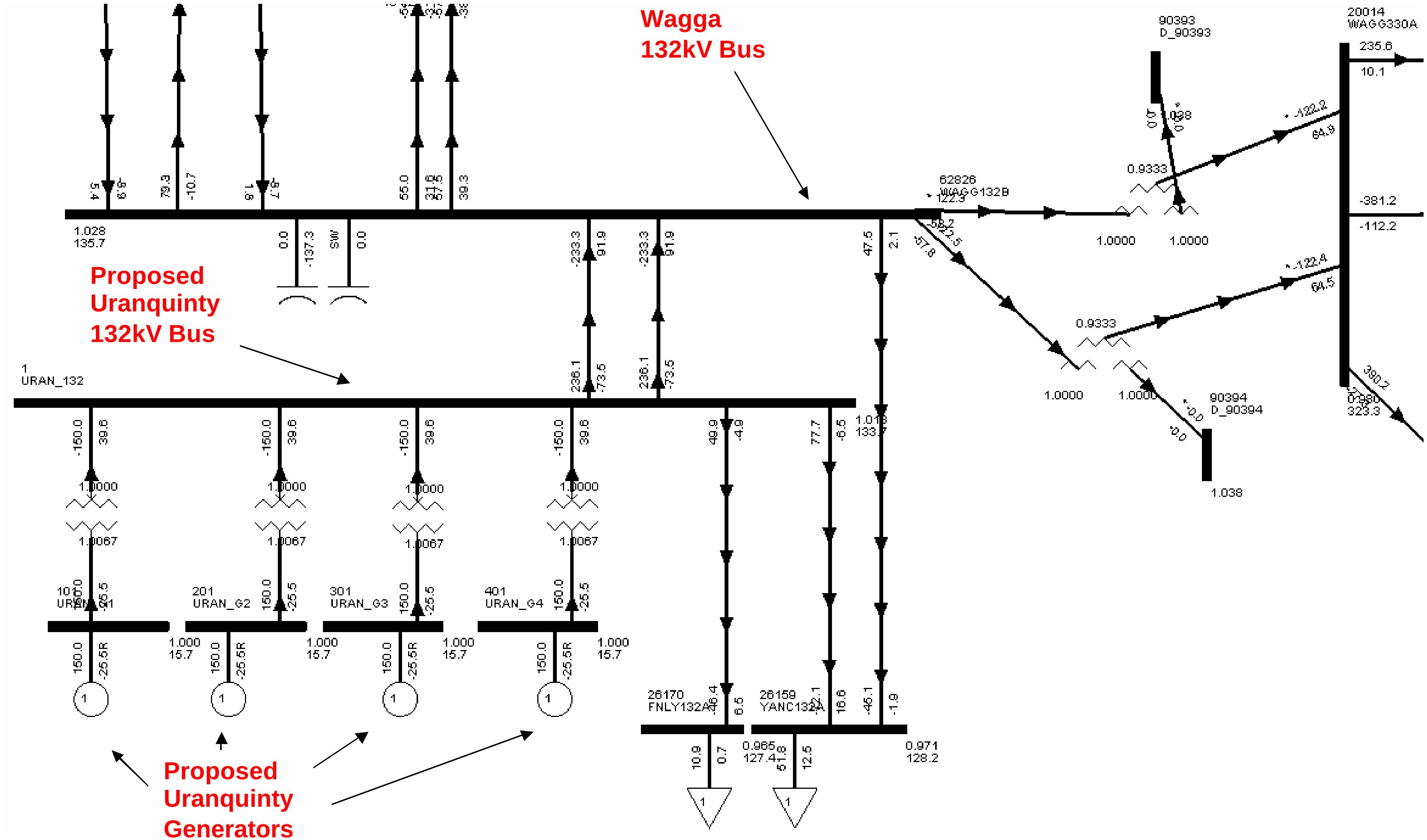



Figure 1: Uranquinty generators and southern network modelled in PSSE

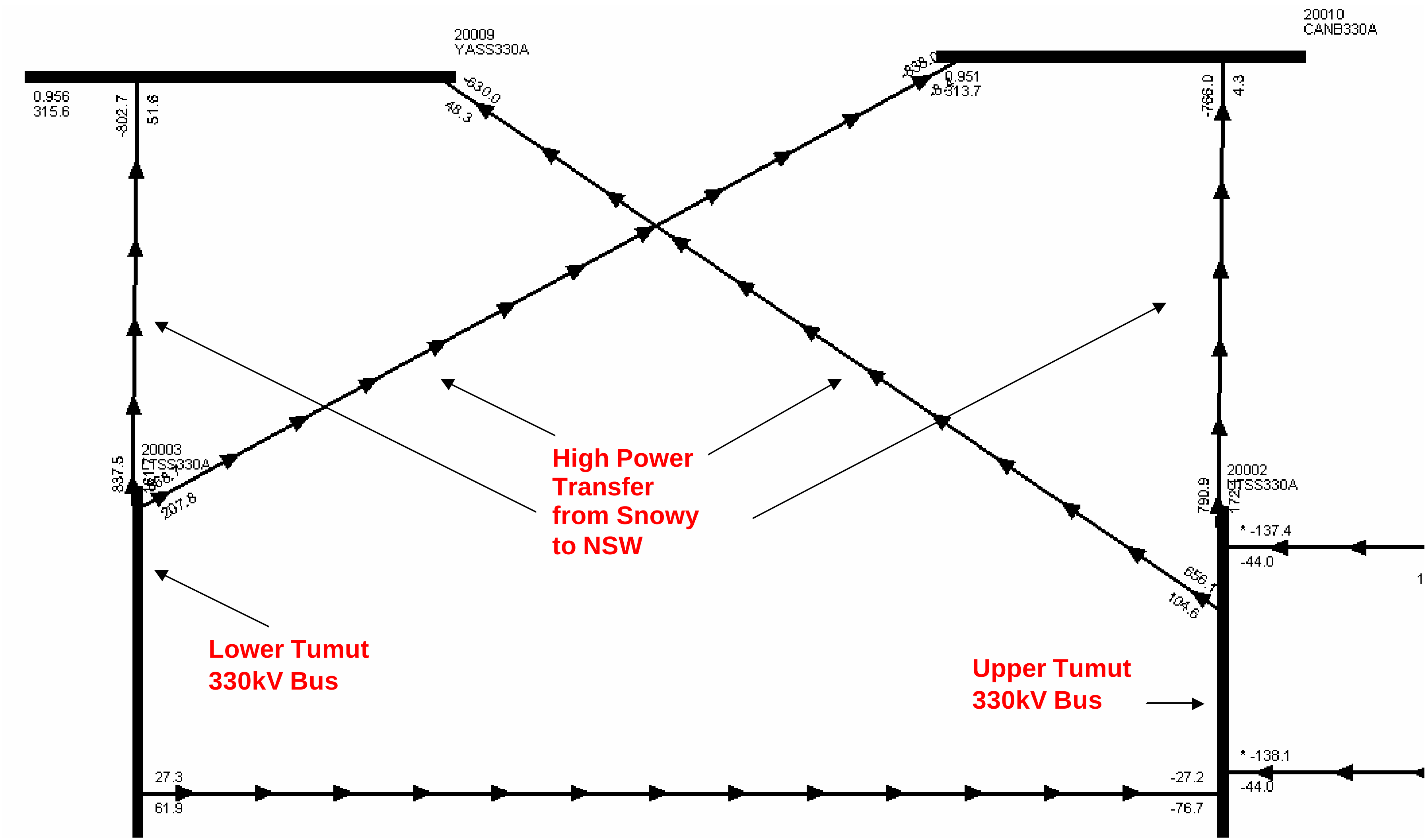



**Figure 2: High power flow transfer from Snow to NSW in PSSE**

# 4. Results

## 4.1. Generation Scheduling

Generation scheduling was performed by ROAM consulting using its 2-4-C market forecasting package to determine the impact of the Uranquinty Power Station for the years 2008, 2013 and 2018. Appropriate forecasts for load and generation were made using the best information available. However no major transmission reinforcements were allowed for between NSW, Snowy and Victoria.

The table below is an extract of the generation and inter-regional transmission flows produced by ROAM for the generation scheduling exercise. Complete results for the years 2008, 2013 and 2018 together with pool prices are supplied separately in files Generation & Transmission Flows for stability.xls and Pool Prices.xls respectively.

**Table 1: Extract of generation scheduling result from ROAM**

| Flow (MW) | QNI | SNOWY1 | SNOVIC | VIC-SA | BASSLINK | | |
|---|---|---|---|---|---|---|---|
| | NSW->QLD | SN->NSW | VIC->SN | VIC->SA | TAS->VIC | | |
| **Forward Limit (MW)** | **500** | **3500** | **1100** | **700** | **590** | **Uranquinty Generation** | **Electricity Price - Snowy Region ($/kWh)** |
| **Reverse Limit (MW)** | **-1100** | **-1100** | **-1900** | **-450** | **-300** | | |
| 09/01/2008 11:30 | -1100 | 576 | -391 | -355 | 587 | 0 | 41.4478 |
| 09/01/2008 12:00 | -1100 | 798 | -400 | -365 | 590 | 0 | 44.3881 |
| 09/01/2008 12:30 | -1100 | 974 | -656 | -277 | 590 | 116 | 49.2249 |
| 09/01/2008 13:00 | -1100 | 1183 | -483 | -397 | 590 | 558 | 49.274 |
| 09/01/2008 13:30 | -1100 | 1351 | -331 | -369 | 590 | 600 | 53.7885 |
| 09/01/2008 14:00 | -1100 | 1522 | -206 | -382 | 590 | 600 | 56.7163 |
| 09/01/2008 14:30 | -1100 | 1611 | -350 | -330 | 590 | 600 | 59.205 |
| 09/01/2008 15:00 | -1100 | 1799 | -331 | -378 | 590 | 600 | 59.4083 |
| 09/01/2008 15:30 | -1100 | 1872 | -393 | -360 | 590 | 600 | 59.2941 |
| 09/01/2008 16:00 | -1100 | 1806 | -340 | -393 | 590 | 600 | 59.4908 |
| 09/01/2008 16:30 | -1100 | 1726 | -154 | -410 | 590 | 600 | 59.8896 |
| 09/01/2008 17:00 | -1100 | 1370 | -311 | -356 | 590 | 600 | 60.1192 |
| 09/01/2008 17:30 | -1100 | 858 | -228 | -290 | 561 | 600 | 55.445 |
| 09/01/2008 18:00 | -1100 | 322 | -260 | -183 | 574 | 0 | 46.9211 |
| 09/01/2008 18:30 | -1100 | 133 | -448 | 45 | 525 | 0 | 39.835 |

The table below indicates the average generation, percentage of time generating per year and the total annual generation for the Uranquinty Power Station. For each year the total annual generation is more for the lower transfer limit between Snowy and NSW.

**Table 2: Uranquinty Generation Data for the years 2008, 2013 and 2018**

| | | Snowy->NSW Transfer Limit | |
|---|---|---|---|
| | | **3500MW** | **3000MW** |
| **2008** | *Average Generation* | 484.74MW | 484.94MW |
| | *Time Generating per year* | 5.66% | 5.66% |
| | *Total Annual Generation* | 240.92GWh | 241.02GWh |
| **2013** | *Average Generation* | 509.4MW | 507.37MW |
| | *Time Generating per year* | 5.62% | 5.63% |
| | *Total Annual Generation* | 251.65GWh | 251.88GWh |
| **2018** | *Average Generation* | 502.86MW | 503.09MW |
| | *Time Generating per year* | 5.37% | 5.37% |
| | *Total Annual Generation* | 237.35GWh | 237.46GWh |

From the above table it can be seen that varying the transfer limit between Snowy and NSW has negligible effect on Uranquinty generation. The small variations probably have more to do with the probabilistic way 2-4-C deals with generation outages than any variation in the transfer limits.

## 4.2. Load Flow Studies

Load flow studies were performed to determine the impact of generation at Uranquinty on the thermal limits of the existing 330kV and 132kV network in the NSW and Snowy region. Using the generation scheduling results a base case and line out studies were performed for each of the years 2008, 2013 and 2018. These studies determine the amount of reduction in generation at Uranquinty to satisfy the thermal limits on the transmission lines under normal operating conditions and line out conditions.

It was decided that the existing thermal limitations in the lines between Tumut and Murray would not be considered as a constraint in the Snowy area. This is an internal Snowy problem and Snowy schedules its generation to suit.

Table 3 below is an example of the results given by ROAM to determine the line loadings in the Snowy and southern NSW region. The ratings for each line are shown along with the percentage of time overloaded with the minimum and maximum power flow in the lines. To calculate the amount that the Uranquinty generator would have to be cut back, each half hour period was available in PSS/E. The generation at Uranquinty was reduced until the loading on any overloaded lines fell below its individual thermal rating.

The probability of the Uranquinty sets being on and a 330kV line outage of this occurring is very small as the Uranquinty sets are only generating approximately 5% of the year. The forced outage rate of 330kV lines is approximately once every 170km years.

Transgrid estimate the outage time of the 330kV line is 8hrs/year i.e. 0.00092 of time. On the assumption that there could be 1 outage of a single 330kV line a year then approximately there could be a an outage whilst the generator is on line every 20 years. This probability is only applicable for a single 330kV line outage. When considering the 330kV from Snowy north to NSW, there are 4 330kV lines outlined in the load flow studies. Therefore there would approximately be an outage of any of the four (4) 330kV lines whilst Uranquinty is generating once every 5 years. This means Uranquinty generation might have to be restricted for a period of 8 hours every 5 years. On this basis the expected loss of generation would be 0.37% of the values given in the following tables. The above argument is based on the consideration of the 4 330kV lines only. 132kV lines are involved as well. However as the number of lines (330 and 132kV) vulnerable to overload averages 4 in each of the years concerned, the expected loss of generation of 0.37% a year is considered reasonable.

The above overloads occur for a 3,500MW transfer limit between Snowy and NSW. Overloads for a 3,000MW transfer limit are insignificant.

The above indicates that if needed in the future Wambo Power could with very little risk negotiate with NEMMCO to increase the Snowy to NSW transfer limit to 3,500MW when Uranquinty is on line on the understanding that Uranquinty would reduce output if an overload occurs following a line outage.

**Table 3: Extract from 2008 Load flow results with Lower Tumut to Canberra 330kV line OOS**

Uranquinty Station on the Wagga 132kv bus

| | | |
|---|---|---|
| Max Generation | 588 | MW |
| Annual Generation | 240.9178 | GWh |
| Capacity Factor | 4.58% | |

| | |
|---|---|
| 132kv | 330kv |

| From: | Wagga 132 | | | | | | |
|---|---|---|---|---|---|---|---|
| To: | Gadara | Finely | Yanco - 1 | Yanco - 2 | Murrumbrrah | Anm | Yass |
| Min MVA Rating | -110 | -79 | -157 | -157 | -107 | -107 | -144 |
| Max MVA Rating | 110 | 79 | 140 | 140 | 107 | 107 | 144 |
| Min MVA Flow | 0.095999 | 13.83023 | 6.322427 | 6.28304 | 0.013277 | 0.121941 | 0.743168 |
| Max MVA Flow | 90.27218 | 39.17581 | 47.31898 | 46.56211 | 85.77617 | 73.61892 | 90.93373 |
| Percent time overloaded | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Avg Flow Uranquinty On | 31.88786 | 32.59039 | 34.37756 | 33.78955 | 34.47724 | 36.74949 | 24.99216 |
| Avg Flow Uranquinty Off | -7.41418 | 21.30692 | 18.71815 | 18.39778 | -6.77411 | 12.35717 | -22.3788 |

| From: | Wagga 330 | | | Tumut3_5 | | | Tumut1_2 | | | Murray_5 | | Tumut3_5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| To: | Darlington Point | Lower Tumut | Jindera | Yass | Tumut1_2 | Murray_5 | Yass | Murray_5 | Canberra | DDTS - 1 | DDTS - 2 | Canberra |
| Min MVA Rating | -572 | -1069 | -955 | -1063 | 736 | -736 | -915 | -736 | -915 | -1045 | -1045 | Off |
| Max MVA Rating | 569 | 1069 | 955 | 1041 | 736 | 736 | 915 | 736 | -915 | 1045 | 1045 | |
| Min MVA Flow | 117.6092 | 86.69908 | 16.9005 | 17.57561 | 8.417091 | 13.45362 | 20.79381 | 7.514757 | 15.43061 | 1.553514 | 1.685164 | |
| Max MVA Flow | 233.4605 | 575.1668 | 342.566 | 927.6741 | 260.3889 | 605.5965 | 732.3491 | 1042.979 | 1056.745 | 671.6809 | 673.7384 | |
| Percent time overloaded | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.45% | 0.28% | 0.00% | 0.00% | |
| Avg Flow Uranquinty On | 152.4274 | -78.0442 | 44.86556 | 289.9428 | -22.267 | -170.661 | 238.6604 | -243.248 | 426.2181 | 115.1591 | 115.5005 | |
| Avg Flow Uranquinty Off | 118.302 | -248.219 | 0.959252 | -94.4418 | -90.7335 | -12.5238 | -51.0064 | 60.98728 | 33.17494 | 118.5162 | 118.8742 | |

#### 4.2.1. 2008

For the year 2008 there are no thermal overloads under system normal conditions with Uranquinty generating. The table below indicates the total energy loss due to line out conditions. As explained previously the probability of an outage of any of these lines is very small. Therefore the energy lost due to an outage given would be approximately 0.37% of the values given in the tables..

**Table 4: Total Uranquinty generation energy loss for 2008**

| Line Out Of Service | Overloaded Line | Energy Lost (GWh) |
|---|---|---|
| Lower Tumut - Canberra OOS | Upper Tumut to Canberra [Rating: 915MVA] | 8.1435 |
| Upper Tumut - Yass OOS | Upper Tumut to Canberra [Rating: 915MVA] | 2.7380 |
| Wagga330 - Jindera OOS | Wagga 132 to Anm [Rating: 107MVA] | 8.4237 |

**Total Energy Loss** 19.3052 GWh

#### 4.2.2. 2013

The table below outlines the total energy loss due to line out conditions. As with 2008 there are no overloads under normal conditions.

**Table 5: Total Uranquinty generation energy loss for 2013**

| Line Out Of Service | Overloaded Line | Energy Lost (GWh) |
|---|---|---|
| Lower Tumut - Canberra OOS | Upper Tumut to Canberra [Rating: 915MVA] | 4.9525 |
| Lower Tumut - Yass OOS | Wagga 132 - Gadara [Rating: 110MVA] | 0.1860 |
| Wagga330 - Jindera OOS | Wagga 132 to Anm [Rating: 107MVA] | 15.9868 |
| Wagga330 - Lower Tumut OOS | Wagga 132 to Gadara [Rating: 110MVA] | 0.0960 |

**Total Energy Loss** 21.2213 GWh

#### 4.2.3. 2018

For the year 2018 there are more cases where the generation at Uranquinty will have to be reduced however the total is less then previous years.

**Table 6: Total Uranquinty generation energy loss for 2018**

| Line Out Of Service | Overloaded Line | Energy Lost (GWh) |
|---|---|---|
| Lower Tumut - Yass OOS | Upper Tumut to Canberra [Rating: 915MVA] | 2.8200 |
| Upper Tumut - Canberra OOS | Lower tumut to Canberra [Rating: 1041MVA, -1063MVA] | 5.2080 |
| Upper Tumut - Murray OOS | Upper Tumut to Lower Tumut [Rating: 736MVA] | 1.2830 |
| Upper Tumut - Yass OOS | Upper Tumut to Canberra [Rating: 915MVA] | 6.7160 |
| Wagga330 - Jindera OOS | Wagga132 to Anm [Rating: 107MVA] | 1.7892 |
| Wagga330 - Lower Tumut OOS | Wagga132 to Gadara [Rating: 110MVA] | 0.3350 |

**Total Energy Loss** 18.1512 GWh

## 4.3. Stability Studies

Stability studies were undertaken with high power transfer from Snowy to NSW and high power transfer from Snowy to Victoria. The results of the stability studies are as follows.

### 4.3.1. High power flow from Snowy to NSW

The table below indicates the critical clearing times of the Uranquinty sets under high power transfer conditions from Snowy to NSW.

**Table 7: Critical Clearing times for the Uranquinty sets**

| Location of Fault | Clearing Line | Critical Clearing Time (ms) 3-phase | Critical Clearing Time (ms) 2-phase-to-ground |
|---|---|---|---|
| Wagga 330 | Lower Tumut | 410 | >500 |
| | Darlington Point | 438 | >500 |
| | Jindera | 424 | >500 |
| Lower Tumut | Upper Tumut | 208 | 284 |
| | Yass | 155 | 220 |
| | Canberra | 164 | 230 |
| | Murray | 202 | 276 |
| Upper Tumut | Yass | 184 | 290 |
| | Canberra | 186 | 286 |
| | Murray | 212 | 320 |
| Proposed Uranquinty 132kV Bus | Wagga132B | 291 | >500 |

To show the impact on the Snowy generators, critical clearing times were found for the Snowy generators with the Uranquinty sets in and out of service. These results indicate that with a high power transfer from Snowy into the NSW network, the Uranquinty sets significantly improve the stability of the Snowy region.

**Table 8: Critical Clearing times for the Lower Tumut sets with and without Uranquinty**

| | | Critical Clearing Time (ms) | | | |
|---|---|---|---|---|---|
| | | With Uranquinty | | Without Uranquinty | |
| Location of Fault | Clearing Line | 3-phase | 2-phase-to-ground | 3-phase | 2-phase-to-ground |
| Lower Tumut | Yass | 155 | 220 | 105 | 150 |
| | Canberra | 164 | 230 | 115 | 160 |
| Upper Tumut | Yass | 184 | | 140 | |

The stability graphs below show that the presence of the Uranquinty sets reduce damping of the existing Snowy hydro generators.

### 4.3.2. High power flow from Snowy to VIC

Stability studies were also undertaken with high power flow from Snowy to Victoria. The table below indicates results for stability studies run on a Murray set with and without Uranquinty generating. Power transfer from the Snowy to Victoria was 1900MW

**Table 9: Critical Clearing times of the Murray sets with and without Uranquinty**

| | | Critical Clearing Time (ms) | | | |
|---|---|---|---|---|---|
| | | With Uranquinty | | Without Uranquinty | |
| **Location of Fault** | **Clearing Line** | **3-phase** | **2-phase-to-ground** | **3-phase** | **2-phase-to-ground** |
| Murray | Dederang | 425 | >500 | 420 | >500 |

As shown in the table, with high power flow from Snowy to Victoria the stability of Snowy generators are not significantly affected by the Uranquinty generators being on line. With high power transfer south there is no stability constraint and therefore the additional generators at Uranquinty should not have a great affect on stability in the Snowy region.

# 5. Conclusions

## 5.1 Under Present Market Conditions

Under present market conditions there appear to be no restrictions offered by the network in exporting 600MW from Uranquinty when bidding at $50/MW.

If conditions change and the transfer limits which at present apply between regions and in particular between Snowy and NSW result in restrictions on generation at Uranquinty then it may be possible to negotiate with NEMMCO to increase the transfer limits on the basis that if a line becomes overloaded during an emergency then Uranquinty would restrict generation. The indications are that any resulting restrictions in generation would be minor.

## 5.2 Stability

With high power transfers north from Snowy, Uranquinty improves transient stability quite significantly. System damping with Uranquinty operating is satisfactory.
With high power transfers south from Snowy, stability is not a problem. The presence of Uranquinty has insignificant effect.

# Appendices

## Appendix A: Minutes of Meeting with Transgrid on 22nd November 2005 from 10.00am to 11.00am

## Appendix B: Wagga Power Station – Construction of Grid Connections

## Appendix C: Extract of Uranquinty Generator Planning Data

## Appendix D: ROAM Consulting 2-4-C Model Description

## Appendix E: Stability Study Generator Responses

# Appendix A: Minutes of Meeting with Transgrid on 22nd November 2005 from 10.00am to 11.00am

Minutes of Meeting with Trangrid on 22nd November 2005 from 10.00am to 11.00am

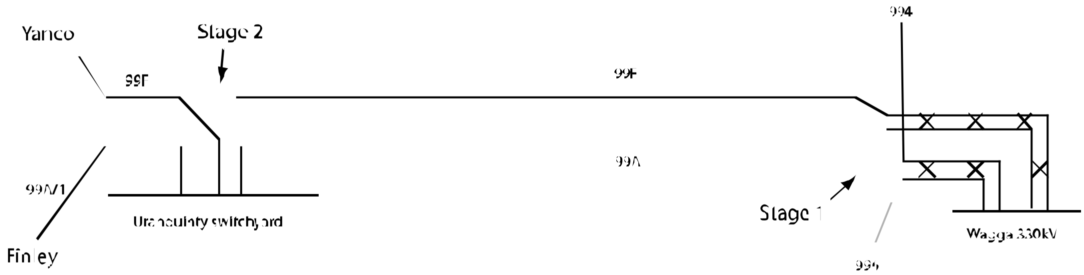
Attendees: Garrie Chubb, Dr. Colin Parker, Gordon Burbidge and George Brooks of Transgrid
Max Michael, Chris Knightly and Teck Wai Chan of HMA Consulting

Objective: Consultation with Transgrid on details of interconnection limitations and the conditions under which they occur, as applicable for the connection of a 600MW generator at Uranquinty

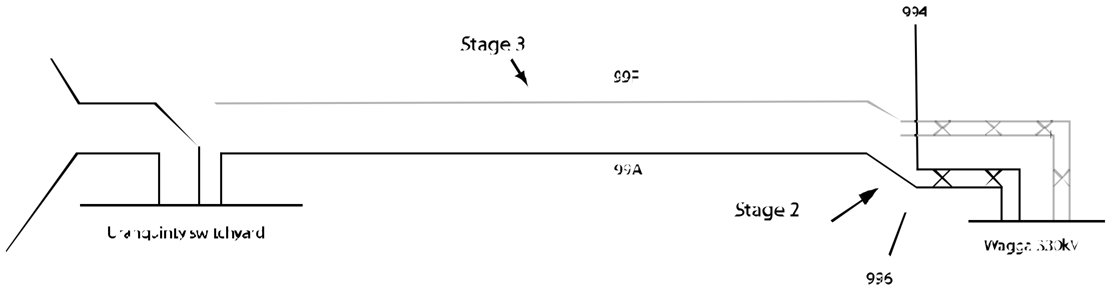
| S/N | HMAC Requests | Transgrid Replies | Action required |
|---|---|---|---|
| 1 | Transmission lines rating, including 15minutes short time rating | Transgrid advised that this data is available from Nemmco web page under the transmission & distribution section. | HMAC to acquire this data. |
| 2 | HMAC requested details of loading conditions and limitations that Transgrid had used in their power flow studies as reported in the Transgrid Planning Report 2005. Hmac enquires if there is any in-house report of these details that can be released to marrket participant. | Transgrid infromed that they would look into providing HMAC with any reports that may be available indicating the limitations and conditions under which their studies are done. | Trasngrid to advise. |
| 3 | HMAC informed that ROAM Consulting may be engaged to provided additional information on the power flow in the region as the result of the dispatch engine. | Transgrid informed that ROAM Consulting would have all the limit equations required. | For information. |
| 4 | - | Transgrid informed that generation from Snowy is subject to pool price and not loading condition. Therefore it may not necessarily generate during peak load. | For information. |
| 5 | - | Transgrid explained the various limitations and constrains of the power transfer between NSW and VIC in relation to the cutsets mentioned in the Transgrid Planning Report 2005. | For information. |
| 6 | - | Transgird informed that when the line between Lower Tumut and Wagga is forced out, the 132kV connection between Wagga and Yass is opened. | For information. |
| 7 | - | Transgrid informed that a 15-minute emergency rating is used for lines connecting into Murray, whereas a 5-minute emergency rating with load shedding is used in Victoria. | For information. |

| | | | |
|---|---|---|---|
| 8 | - | Transgrid informed that studies on the connection details between the proposed Uranquinty power station and Wagga have been carried out between Transgrid and ERM. The reports can be made available. (Mr. Praveen). | HMAC will contact ERM if needed. |
| 9 | HMAC requested details including the impedance of the proposed series reactor between the proposed Uranquinty power station and Wagga 132kV substation. | - | Transgrid will provide the details as requested. |
| 10 | HMAC requested details on transient stability limitations on power transfers | Transgrid stated that it uses 20 cases to assess the stability of the system | Transgrid offered to provide data for the 20 cases |

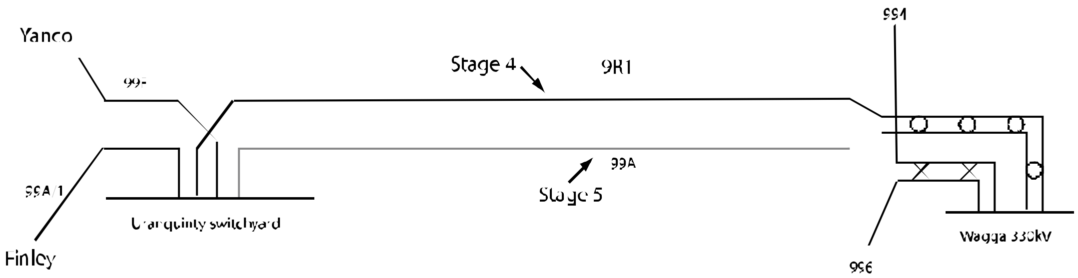
## *Appendix B: Wagga Power Station – Construction of Grid Connections*



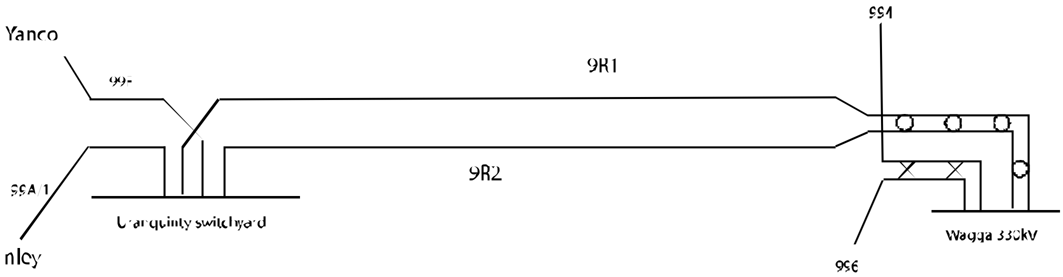

Stage 1 – connect 99A to 996 at the end of the steel tower section
Stage 2 – turn 99A into Uranquinty switchyard and re-establish supply to Finley via 99A/1. Cut 99F and connect to the Uranquinty bus.




Stage 3 - dismantle 99F back towards Wagga including the steel tower section.




Stage 4 – reconstruct 99F between Uranquinty and Wagga including the steel pole section and form 9R1.
Stage 5 – Uranquinty is now supplied through 9R1. Resurrect 996 at the end of steel tower corridor and dismantle 99A for reconstruction.




Stage 6 - Final arrangement with 99A reconstructed to form 9R2

# *Appendix C: Extract of Uranquinty Generator Planning Data*

Wambo

GAS POWER

PLANNING DATA

AS PER

SCHEDULES 5.5.1, 5.5.2, 5.5.3, 5.5.4 and 5.5.5

OF NEC

WPV
2xV94.2 GTPP

## Schedule 5.5.1 Generating Unit Design Data

### Power Station Technical Data:

| Data Description | Units | Data |
|---|---|---|
| Connection Point to Network | Text, diagram | Power Station Substation of Uranquinty as per figure 4 of TransGrid Brief Report of November 2003 |
| Nominal voltage at connection to Network | kV | 132 |
| Total Station Net Maximum Capacity (NMC) | MW (sent out) | 325 |

### At Connection Point:

| Data Description | Units | Data |
|---|---|---|
| Maximum 3 phase short circuit infeed calculated by method of AS 3851 (1991) | | |
| · Symmetrical | kA | 7.5 |
| · Assymetrical | kA | 13.9 |
| Minimum zero sequence impedance | % on 100 MVA base | 2.5 ±15% |
| Minimum negative sequence impedance | % on 100 MVA base | 7.35 ±15% |

### Individual Generating Unit Data:

| Data Description | Units | Data |
|---|---|---|
| Rated MVA | MVA | 204 |
| Rated MW (Sent Out) | MW (sent out) | 162.8 |

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| Data Description | Units | Data |
|---|---|---|
| Nominal Terminal Voltage | kV | 15.75 |
| Auxiliary load at PMAX | MW | 1.31 |
| Rated Reactive Output at PMAX | MVAr (sent out) | 127 |
| Minimum Load (ML) | MW (sent out) | 16 |
| Turbo Generator Inertia Constant | MWs/rated MVA | 5.55 |
| Short Circuit Ratio | | 0.50 |
| Rated Stator Current | A | 7478 |
| Rated Rotor Current at rated MVA and Power Factor, rated terminal volts and rated speed | A | 1034 estimated |
| Rotor Voltage at which IROTOR is achieved | V | 268 estimated |
| Rotor Voltage capable of being supplied for five seconds at rated terminal volts and rated speed | V | 417 |

**Generating Unit Resistance:**

| Data Description | Units | Data |
|---|---|---|
| Stator Resistance | % on MBASE | 0.079 |

**Generating Unit Reactances (Unsaturated):**

| Data Description | Units | Data |
|---|---|---|
| Direct Axis Synchronous Reactance | % on MBASE | 241 ±15% |
| Direct Axis Transient Reactance | % on MBASE | 23.4 ±15% |
| Direct Axis Sub-Transient Reactance | % on MBASE | 18.9 ±15% |
| Data Description | Units | Data |
| Quadrature Axis Transient Reactance | % on MBASE | 48.3 ±15% |
| Quadrature Axis Sub-Transient Reactance | % on MBASE | 20.8 ±15% |

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| Data Description | Units | Data |
|---|---|---|
| Zero Sequence Reactance | % on MBASE | 10.0 ±15% |
| Negative Sequence Reactance | % on MBASE | 19.8 ±15% |
| Potier Reactance | % on MBASE | 21.5 ±15% |

**Generating Unit Time Constants (Unsaturated):**

| Data Description | Units | Data |
|---|---|---|
| Direct Axis Open Circuit Transient | Seconds | 13.55 |
| Direct Axis Open Circuit Sub-Transient | Seconds | 0.040 |
| Direct Axis Damper Leakage | Seconds | 0.060 |
| Quad Axis Open Circuit Transient | Seconds | 2.5 |
| Quad Axis Open Circuit Sub-Transient | Seconds | 0.15 |

**Charts:**

| Data Description | Units | Data |
|---|---|---|
| Capability Chart | Graphical data | Refer to diagram LD/WE03106/3600/Mg |
| Open Circuit Characteristic | Graphical data | Refer to diagram LK/WE03106/3600/Mg |
| Short Circuit Characteristic | Graphical data | R1 Refer to diagram LK/WE03106/3600/Mg |
| Zero power factor curve | Graphical data | To come |

**Generating Unit Transformer:**

| Data Description | Units | Data |
|---|---|---|
| Number of windings | Text | Three |
| Rated MVA of each winding | MVA | 210 |
| Principal tap rated voltages | kV/kV | 15.75/132 |
| Positive Sequence Impedances (each wdg) | (a + jb) % on 100 MVA base | (0.02+j6)% |

WPV
2xV94.2 GTPP

| Data Description | Units | Data |
|---|---|---|
| Zero Sequence Impedances (each wdg) | (a + jb) % on 100 MVA base | (0.02+j5)% |
| Tapped Winding | Text, diagram | High Voltage |
| Tap Change Range | kV - kV | (+)15% - (-)5% |
| Tap Change Step Size | % | 1.25% |
| Tap Changer Type, On/Off load | On/Off | On |
| Tap Change Cycle Time | Seconds | Three |
| Vector Group | Diagram | Ynd |
| Earthing Arrangement | Text, diagram | HV Solid |
| Saturation curve | Diagram | Refer to the enclosed diagram "Typical Saturation Curve for 210 MVA Generator Transformer" |

**Generating Unit Reactive Capability (At machine terminals):**

| Data Description | Units | Data |
|---|---|---|
| Lagging Reactive Power at PMAX | MVAr export | 110 |
| Lagging Reactive Power at ML | MVAr export | 153 |
| Lagging Reactive Short Time capability at rated MW, terminal voltage and speed | MVAr (for time) | To come |
| Leading Reactive Power at rated MW | MVAr import | 68 |

**Generating Unit Excitation System:** (Also refer to Technical Data of SEE, Description of the SEMIPOL Excitation Equipment, SEMIPOL further description and power System stabiliser of SEMIPOL and IEEE)

| Data Description | Units | Data |
|---|---|---|
| DC Gain of Excitation Control Loop | V/V | To come |

# *Appendix D: Description of ROAM Consulting 2-4-C Model*

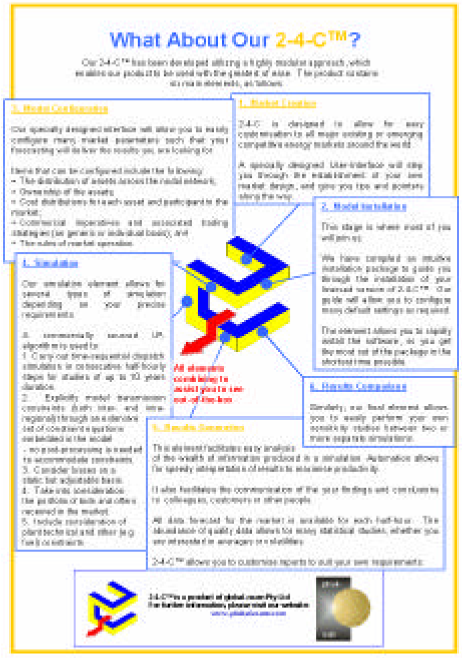
## Description of 2-4-C Model

ROAM Consulting has developed a comprehensive and versatile approach to the prediction of future market outcomes, incorporating the 2-4-C market-forecasting package[1].

2-4-C generates its forecasts of the market on the basis of rigorous modelling of the probable operation of the market. Key features (as standard) of 2-4-C include the following:

- Simulation of market operation:
  - 2-4-C has been designed specifically to mimic the operation of the market;
  - 2-4-C uses an embedded commercial LP engine under licence from a US supplier;
- The time-sequential nature of the simulation allows the product to model 17,520 discrete half-hourly load points per year;
- The Monte-Carlo based plant outage modelling adds an additional degree to the existing rigour of the product;
- The standard nodal configuration of the model allows the capability to simulate the frequency and impact of the incidence of transmission constraints.

The 2-4-C Package



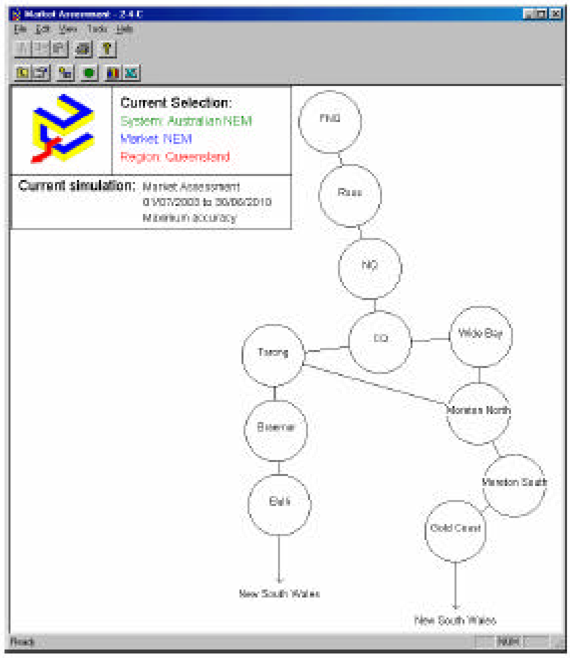

Though the product has been robustly designed such that it can model any existing market, or those under development, 2-4-C has been specifically configured to the NEM. In this way, 2-4-C models all key physical and commercial parameters of the competitive NEM. In addition, the Rule Set used within 2-4-C faithfully represents the rules of operation of the NEM.

[1] Please refer to the following for further information on the capability of 2-4-C:
(a) The product brochure for 2-4-C;

### Standard Modelling Configuration of 2-4-C

The current NEM area is now modelled by ROAM Consulting with 18 nodes including Tasmania and with provision for Western Australia.

The 11-node model of the Queensland region is shown in greater detail to the right.




## Features of 2-4-C

### Faithful Market Mimicking

The modelling approach uses a Linear Programming algorithm to mimic the bid-based dispatch approach of the NEM (based on the current NEM dispatch rules).

Generator bids can be divided into a maximum of 10 bands per unit (as per NEM rules) and the LP algorithm sorts these bids, adjusted by static intra-regional loss factors, and simulates dispatch on that basis.

Inter-regional transmission losses are modelled on a dynamic basis, according to the NEM rules.

In summary, the 2-4-C market model faithfully mimics all key features of the NEM.

## Time-Sequential Market Modelling

The above simulation proceeds sequentially, in discrete half-hourly steps, as per the operation of the NEM.

Study periods can range from as short as one hour, or one day to a continuous period of 10 years or greater, due to the data storage capabilities of the 2-4-C ODBC database. In any study, each single half-hourly period is modelled, using discrete data points that have been established for every half-hour in the study on the basis of the best available market information.

Modelling on such time-sequential basis offers two types of benefits:

1) Due to the rigour of the modelling, the accuracy of the results generated are much higher than that returned by more generalized market forecasting techniques that are sometimes adopted;

2) As 2-4-C simulates the actual operation of the market a large volume of information is generated for a wide range of variables. Detailed reports, such as those in this report (on average or volatility basis), can be generated readily generated for any of the following:
   a) Basic level information, including:
      i) Dispatch volumes for all generation units;
      ii) Transfers over all interconnectors; and
      iii) Regional pool prices;
   b) More detailed information can be generated, with the benefit of a little additional computation, for variables including:
      i) Cost inputs;
      ii) Operational characteristics;
      iii) Revenue opportunities; and
      iv) Risk exposures.

**Monte-Carlo Based Plant Outage Modelling**

The 2-4-C forecasting product incorporates Monte-Carlo based random outages of generation on a unit-by-unit basis.

**Nodally-Based Transmission Constraint Modelling**

Transmission congestion is modelled explicitly through the nodal configuration of the model, and an extensive set of constraint equations embedded in the model:

1) Importantly, no post-processing is needed to accommodate constraints (as this eliminates the need for inaccurate assumptions and time delays in delivery of a study);

2) Such modelling is applied to both inter-regional and intra-regional constraints;

3) Treatment of constraints in the price establishment process follows NEM guidelines;

4) Of particular interest to this study, the illustration above references the detailed model of the Queensland region that has been used to gain an accurate projection of the likely incidence (and impact) of intra-regional transmission constraints within the Queensland region;

Within 2-4-C, there is no practical limitation on the number of nodes and interconnectors that can be defined.

## (A) The Input Data We Used

2-4-C operates on the basis of a comprehensive database of the Australian National Electricity Market currently assembled for user-friendly, general commercial availability.

Data contained within the 2-4-C database is an amalgamation of many sources within the public domain including:

- The NEMMCO Statement of Opportunity (releases for 2005);
- Annual Planning Statements by Network Service Providers:
  - Powerlink Queensland statements for the years to 2005;
  - TransGrid statement for 2005;
  - VenCorp statements for 2005; and
  - ESIPC Statement for 2005;

- Corporate Annual Reports for many market participants (generators, retailers and network service providers); and
- General reports from market participants.

## Generation Technical Data

Consideration of many technical parameters associated with generation units across the NEM has been included.

### Individual Unit Capacities and Heat rates

Detail of unit capacities and heat rates (for thermal plants) for every unit across the NEM have been collated and included on the basis of information available from the public domain.

Such information has been used in the calculation of corporate bid strategies for each unit in the NEM.

### Unit operational Constraints

Information on unit minimum load (and other) constraints has been provided in the 2-4-C database.

Such information is taken into consideration in the simulation of market operation (to ensure that an infeasible solution is not indicated).

### Forecast Station Availability

Station availability data, as obtained from references in the public domain (including previous annual reports) was used as an input to the randomisation variable of station outages.

## Generation Commercial Data

In the development of the chosen trading strategy for each generator across the NEM, some key commercial data has been required. Such data is assembled in the 2-4-C database and includes the following:

- The intra-regional Marginal Loss Factor (MLF);
- Operations and maintenance cost;
- Fuel cost, which has been computed with reference to:
  - Unit heat rate;
  - Fuel heating value; and
  - Fuel unit price.

## Generator Trading Strategies

A wide range of trading strategies can be considered within 2-4-C.

Variables that will impact on market behaviour include the following:

1) The trading strategies adopted by the various generators as they evolve along with the market (e.g. strategies perhaps specifically focused on asset utilisation, or on short-term profit maximization – perhaps for the purposes of sale price enhancement);

2) The influence on the spot market (over short- and medium-term) by the level of liquidity and pricing levels in the various contract markets that will continue to evolve;

3) The potential for short-term gaming as a result of market power;

4) The effects of any emissions trading or other environmentally-focused trading requirements for greenhouse gases; and

5) More local impacts on station operation due to particulate emissions requirements.

## (B) Assumptions with regard to the Supply System

For the purposes of this description, the supply system is regarded as the physical interconnection between the supply and the demand in the market.

**Nodal Configuration**

As discussed previously, the 2-4-C market-forecasting model operates on a nodal configuration.

The nodal configuration has been specifically designed to allow consideration of the dominant intra-regional constraints, and all inter-regional constraints.

**Transmission Losses**

Losses are modelled commercially in either of two ways, in accordance with existing market rules. Treatment is as follows:

- Inter-regional losses over AC interconnectors are modelled using dynamic loss equations supplied by NEMMCO;
- Intra-regional losses are modelled by a static, but periodically adjustable, marginal loss factor (MLF) relative to a Regional Reference Node (RRN). These MLFs were obtained from NEMMCO (or assumed for new stations).

Losses are physically modelled by the allocation of the total amount of transmission losses to a losses facility located at each node.

ROAM Consulting has performed this allocation on the basis of historical loss distributions.

### Transmission Constraints

For each of the links between the nodes defined in the 2-4-C model, bi-directional constraints can be allocated, and adjusted over time.

This data has been added on the basis of information provided within the relevant planning documentation listed as references in the previous section.

## (C) Assumptions about Market Externalities

There are numerous externalities that will have some impact on the operation of the competitive energy market. Several of these are outlined below.

### The Impact of the Goods and Services Tax

Wholesale market prices to be quoted exclusive of the Goods and Services Tax (GST). Hence, projections of the wholesale spot price are provided net of GST.

### The Impact of a Carbon Tax or Emissions trading

For this review, any impact of any emissions trading regime (or carbon tax) within Australia has not been considered explicitly in the modelling.

However, some data has been provided from the study that would be of use in the creation of such a regime.

### The Impact of The 2% Renewables Directive

All retailers are now required by the Federal Government to source at least 2% of their total energy from renewable sources.

At a gross level, this will ensure that the remaining pool market will be smaller by this 2% amount throughout Australia. However, the directive will have very localized effects depending on the prevalence of renewable energy sources in each local area.

Such effects have been explicitly considered in this model through the adoption of forecasts by Nemmco and Powerlink that account for imbedded renewable energy generation.

# *Appendix E: Stability Study Generator Responses*

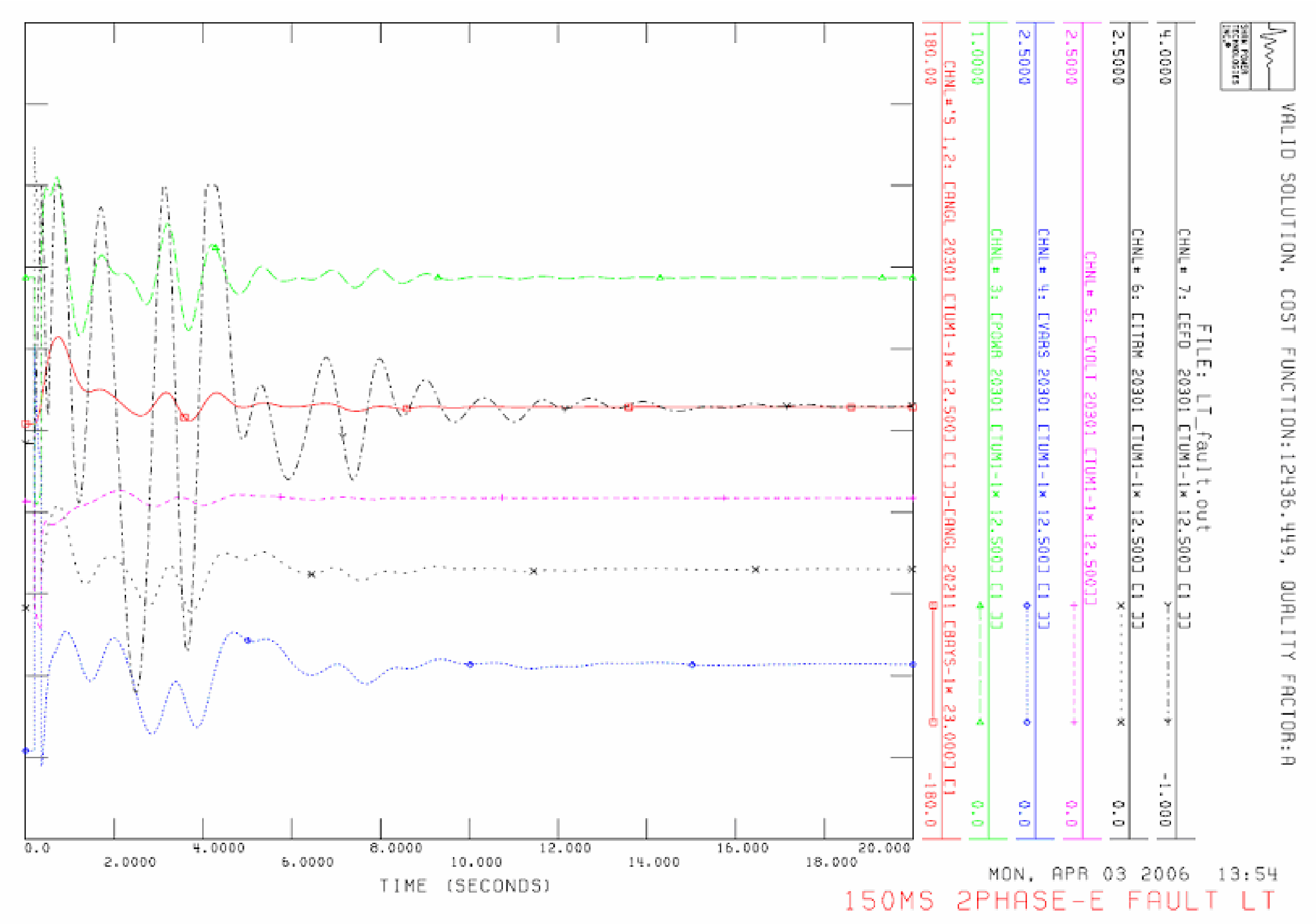



**Figure 3: Generator response of Lower Tumut set with Uranquinty online for 2 phase-to-ground fault at Lower Tumut clearing 330kV line to Yass**

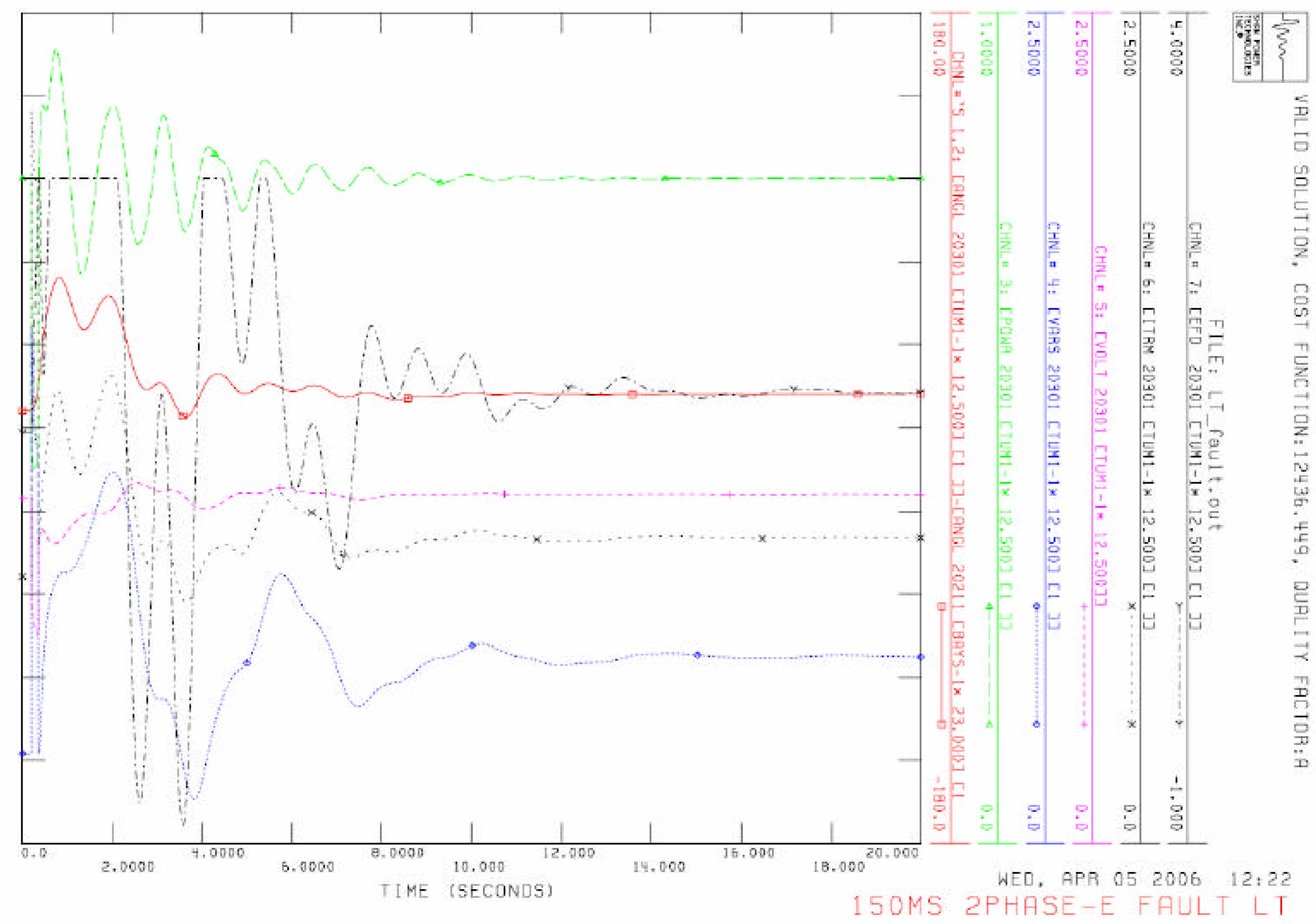



**Figure 4: Generator response of Lower Tumut set with Uranquinty offline for 2 phase-to-ground fault at Lower Tumut clearing 330kV line to Yass**