Roaring40s
THINKING ENERGY

04 August 2008

Mr Ian Woodward
Chairman, Reliability Panel
PO Box A2449
SYDNEY SOUTH NSW 1235

By email (submissions@aemc.gov.au)

Dear Mr Woodward

**REVIEW OF TASMANIAN FREQUENCY OPERATING STANDARDS FOR TASMANIA**

Roaring 40s understands that Reliability Panel requires further information on the following the mechanism by which wind generation in Tasmania would be adversely impacted by tighter frequency standards and specifically, the mechanism by which Tasmanian wind farms would be placed at a disadvantage to mainland Australian sites. Some further information on the suitability of "multi-machine" combine cycle gas plant is also provided in Appendix B.

This submission explains and illustrates what Roaring 40s believe to be the primary mechanism by which the Tasmanian Frequency Operating Standard impacts Tasmanian wind generation, namely high raise frequency control ancillary service (FCAS) costs during periods of low Tasmanian system load. The attached appendix A demonstrates in detail how a cost based FCAS pricing outcome can result in regular and sustained periods when the FCAS liability on wind generation exceeds the potential energy market earnings. Under these circumstances, the cost impact on the wind generation is capped at forgone revenue minus variable operations and maintenance costs as the generator withdraws from the market. The reasons for this are explained in the following paragraphs.

Firstly, as the issues of concern arise from limited availability of raise FCAS services, the following considerations apply to the low frequency parameters of the frequency operating standard.

Under existing Tasmanian market conditions, fast contingency raise FCAS (R6 and R60) would seem to be priced as a "bi-product" of energy production. That is, R6 and R60 are supplied (and priced) as a small incremental cost when Hydro generation is run at or around efficient load. This is particularly apparent during overnight conditions where Hydro generation is backed off to the point where the Tasmanian regional reference price (RRP) separates above Victorian RRP. Under these conditions Hydro plant is able to recover the opportunity cost of operation primarily through the energy price. This is consistent with observations of historical FCAS and energy price outcomes in Tasmanian in recent years.

For a future scenario with increased wind penetration, wind generation and imports over Basslink could provide the bulk of Tasmanian load during co-incident higher wind and lower load periods. In the absence of new entrant FCAS providers, Hydro plant would need to be operating at lower loading levels in order to provide the Tasmanian local raise FCAS requirements. Due to the high level of wind generation, the additional output from Hydro plant will push back on Basslink flows and ensure that the Tasmania and Victorian energy prices stay connected.

On the assumption that the National Electricity Market retains it's strong diurnal pricing patterns, the Hydro plant providing local raise FCAS will only cover a proportion of the opportunity cost of water during periods of low energy price and (in the absence of alternate FCAS providers), local raise FCAS would be priced to ensure full recovery of the opportunity cost of the water consumed.

Pricing of FCAS provision by this hydro plant can be calculated by considering the revenue earned from the energy market, the opportunity cost of water under efficient loading and the reduced efficiency of the Hydro plant at low loading levels. The price must then be adjusted to account for the scaling required to neutralise the effect of the contingency FCAS recovery mechanism that places the liability for a proportion of the market FCAS costs back on FCAS providers.

The appendix contains an example of FCAS pricing under a higher wind production, low Tasmanian load scenario. While plant specific data on efficiency and loading level constraints would add precision, the example clearly illustrates how cost based pricing of R6 FCAS would result in liabilities on wind generation in excess of the energy market earnings of that generation.

In the absence of low cost fast contingency raise FCAS providers entering the Tasmanian market with substantial volume, wind generation in Tasmania is likely to be exposed to sustained periods of either high contingency raise FCAS liabilities or self curtailment of production when contingency raise FCAS liabilities exceed energy market earnings minus the variable operation and maintenance cost of the wind turbines.

This effect will occur to some extent under the existing frequency standards, and any proposal to tighten the Tasmanian frequency standards will further increase the contingency raise FCAS requirement and will increase the costs to Tasmanian wind generation projects. This will of course, reduce the attractiveness of these sites relative to alternative mainland sites.

Roaring 40s understands that this effect is not generally present in electricity market modelling, and occurs in this case due to the small size of the Tasmanian system and the unique combination of wind and hydro generation together with DC transmission technology that supplies this system. Roaring 40s has however, identified that this mechanism as a major sensitivity to the current cost-benefit exercise under higher wind penetration scenarios.

Roaring 40s encourages the Reliability Panel to fully consider this mechanism and report on the economic impact on Tasmanian wind projects. It is suggested that Tasmanian region wind penetration scenarios of 300, 600, 900 and 1200MW of installed wind capacity should be considered.

In addition to the raise FCAS issue described above, Roaring40s also considers it likely that a combination of higher wind penetration and new, less frequency tolerant generation will present challenges to maintaining effective over frequency generation shedding (OFGS) and under frequency generation shedding schemes (UFLS) cover. Under the existing NER, it is not immediately clear how NEMMCO would manage pending or actual scenario where the combination of generation plant mix and operational frequency standard which precluded satisfactory OFGS and UFLS coverage for the Tasmanian region. The options here would appear to be limited to accepting reduced OFGS and UFLS cover, preventing connection of new generation plant or curtailing generation plant in the operational time frame. The last two options have potential to adversely impact wind project economics.

Roaring 40s considers it essential that The Reliability Panel investigate the impact of any proposed new frequency standard on the feasibility of the OFGS and UFLS schemes under higher wind penetration scenarios, and provide detailed as to how a conflict between connecting or operating new generation and maintaining effective OFGS and UFLS systems would be resolved. It is suggested that scenarios of 300, 600, 900 and 1200MW of installed wind capacity should be considered.

Thank you for the opportunity to provide comments on these matters. Please contact Andrew Jones on 0400 537 944 if there are any questions, or indeed if there is and further information Roaring 40s could provide the Panel to assist in this exercise.

Yours Sincerely

J. Titch

John Titchen
General Manager Business Development

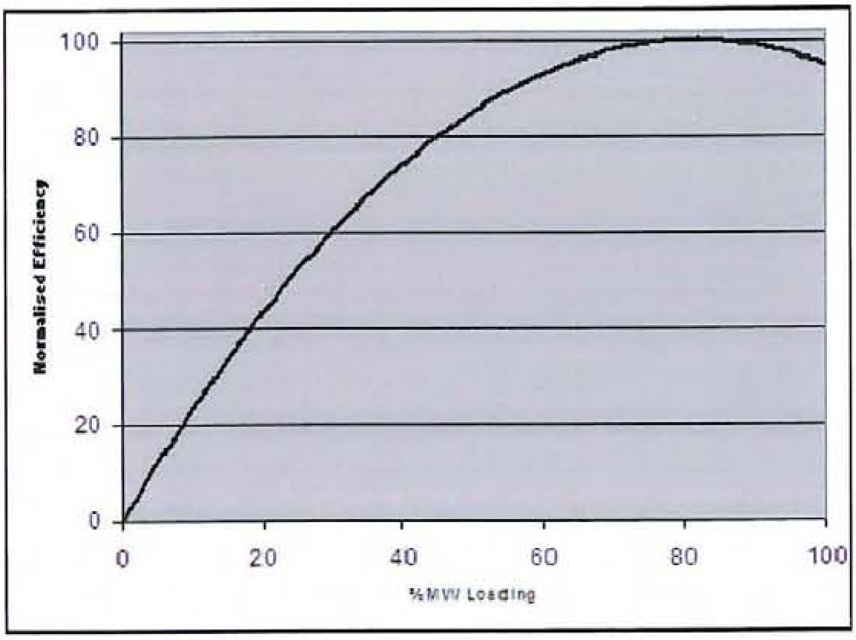
**Appendix A- Example of FCAS cost sensitivity to operating frequency standard and resultant impact Tasmanian wind farm economics.**

This example illustrates the impact of opportunity cost FCAS pricing by Hydro plant on R6 contingency FCAS services under "over night" Tasmanian demand conditions and instantaneous wind penetration of 500MW.

**Key inputs and sensitivities**

**Hydro plant efficiency**
A typical efficiency curve for Francis turbine Hydro plant is used due to the confidential nature of specific plant data. The actual (normalised) curve is shown below. For simplicity of calculation, a quadratic approximation of normalised efficiency:

Eff= -0.0151x(% MW loading)^2 + 2.4617(% MW loading)^ - 0.0719.




The Reliability Panel could seek to obtain plant specific efficiency curves to ensure the precision of their calculations.

**Hydro plant loads**
The FCAS pricing is based on the opportunity cost of operating the FCAS providing Hydro plant at 50% loading to achieve lowest cost operation while avoiding rough running zones. Sensitivity analysis indicates that under a moderate spread between the opportunity cost of water and energy market spot prices, FCAS costs are relatively insensitive to minimum loading levels due to reduced efficiency at lower loading levels. The Reliability Panel could seek plant specific information on the operational considerations that result in loading constraints.

**Tasmanian Local R6 requirements**
A local R6 requirement is defined to cover a 144MW supply shortfall after loss of Basslink import into Tasmania and subsequent frequency control special

protection scheme (FCSPS) action. It should be noted that a reduction in supply shortfall after FCSPS action would reduce the local R6 requirement.

**Opportunity cost of hydro generation**
For the purpose of this illustration, a uniform differential between the opportunity cost of hydro generation and Tasmanian price of $15 is used. This is considered conservative in that:-

- the Tasmania and Victorian prices would remain connected in the off peak periods under consideration and;
- under the majority of circumstances, incremental water being used to produce FCAS would be eligible for Renewable Energy Certificate earnings, so substantially increasing its opportunity cost.

The uniform opportunity cost of water approach is also conservative in that "lower cost" FCAS providers in the west coast of Tasmania (specifically John Butters, Reece, Bastyan and Mackintosh) are prone to intra-year depletion and hence will have higher average water values than the bulk of the Tasmanian hydro generation.

More detailed modelling of opportunity cost of water including intra-regional constraints and REC market linkages should be considered.

**Hydro Plant R6 FCAS capability**
Hydro plant R6 FCAS capability is calculated on the basis of observed FCAS enablement for the month of May 2008. It should be noted that FCAS capability will be dependant on head, particular for lower head stations such as Gordon. The Panel could seek definitive information on FCAS capabilities from either the plant owners or NEMMCO.

**Gas plant operation**
In this example gas plant is disconnected in response to energy market prices well below the short run marginal cost for sustained periods. It is anticipated that the Alinta CCGT would have an R6 capability of less than 15MW in line with the observed behaviour of the more flexible Pelican Point units in the market. The Panel could seek more accurate information on the cost of FCAS provision by the Alinta plant as determined by short run marginal cost, stop and start costs, efficiency at lower loading levels and R6 capability.

**Gunns plant operation**
In this example the Gunns cogeneration plant is included as contributing 15MW of R6 at minimal cost. This is based on the observe capability of the similar Torrens B units in the market. While it has be suggested that Gunns may be able to contribute additional FCAS through tripping of plant load, we note that demand side participation in NEM FCAS markets is very un-usual, and strong argument would need to be made as to why Gunns would behave differently to the majority of similar loads in the NEM. It is also suggested that any inclusion of the Gunns project should be considered conservative given the ongoing uncertainty over the future of this project. As it stands this project would not appear to meet the NEMMCO SOO test for a committed project.

The Panel should seek accurate information on both the probability of this project proceeding and the R6 capability of the specific generation technology being proposed to ensure this is correctly accounted for.

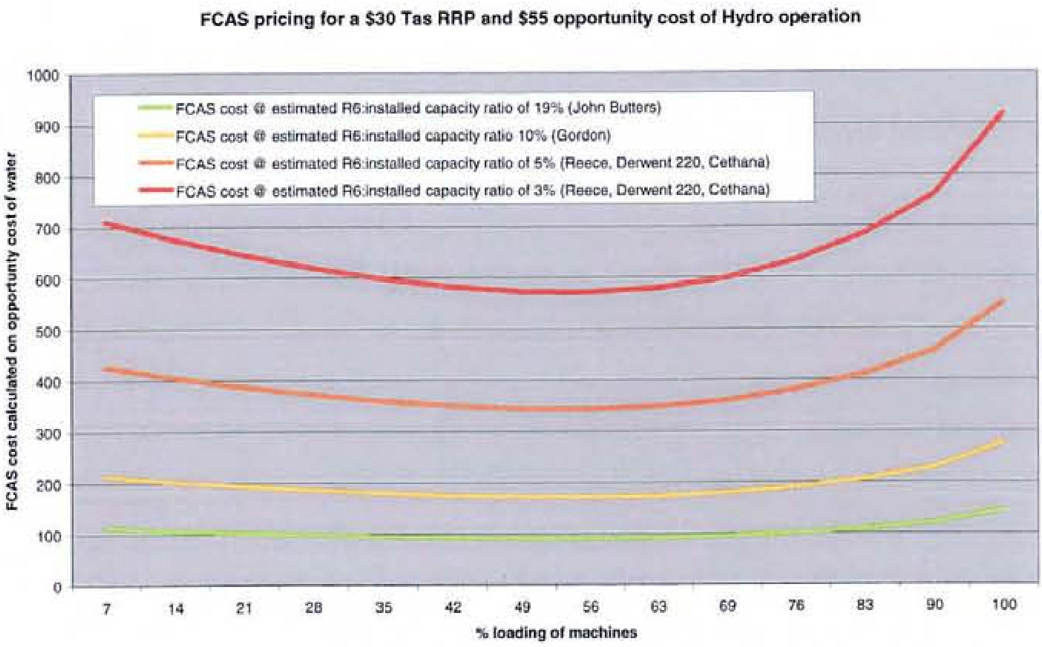
## Calculations

### FCAS cost curves for Hydro plant

The FCAS cost curves for the Hydro plant most capable of providing FCAS are calculated as follows:

Plant MW loading $T_{mw}$
Opportunity cost of MW production, $OP_{mw}$
Tasmanian Regional Reference Price (RRP), $T_{rrp}$
MW capability of machine (MW), $MW_{max}$
R6 FCAS capability of machine, $R6_{max}$
Plant loading, % of MW capacity
Turbine efficiency, $T_{eff} = -0.0151x\ T_{mw}{}^{\wedge}2 + 2.4617x\ T_{mw} - 0.0719$ (polynomial approximation of typical Francis turbine efficiency curve)
Opportunity cost of operating at price below opportunity cost,
$OC_{mw}= (OP_{mw}/T_{eff} - T_{rrp})\cdot /100^{*}\ T_{mw}$
Opportunity cost of FCAS production,
$OC_{R6=}\ OC_{mw} / R6_{max}$

This gives the following curves for Tasmanian Hydro generators.




It can be seen here that the cost of providing FCAS is minimised at around 50% loadings. It is anticipated that this point will move either up or down dependant on the spread between the Tas RRP and the opportunity cost of the of the Hydro generation.

## FCAS supply curve

An indicative FCAS supply curve can be calculated from machine FCAS costs. For the purposes of conservatism, 50% minimum loading levels and water opportunity cost that excludes foregone REC revenue are used. The table below provides the calculation of the cost curve in terms of opportunity cost of water, FCAS pricing to counter recover of FCAS costs from suppliers and the price per MWhr recovered from each MW of wind generation.

| | |
|---|---|
| Tas Load | 1000 |
| Wind MW | 500 |
| Tas RRP | 30 |
| Opportunity cost of hydro generation ($/MWhr) | 55 |
| Hydro efficiency @50% loading (%) | 85 |

| Machine | MW installed | MW R6 FCAS available | Cumulative R6 available | R6 cost unit cost base on opportunity cost of water | Total R6 costs (cost x volume) | ratio R6 costs recovered from hydro providers | Adjusted R6 cost to account for FCAS recovery from providers | MW from Hydro machines to maintain 50% loading | Basslink flow into Tasmania | Wind Generation in Tasmania | wind as percentage of Tasmanian generation | FCAS pricing to achieve cost recovery by suppliers | R6 $MW cost on wind |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gunns | 260 | 15 | 15 | 0 | $0 | | | 0 | 500 | 500 | 100% | $0 | $0 |
| John Butters | 144 | 28 | 43 | 89.24 | $3,837 | 13% | $4,390 | 72 | 428 | 500 | 87% | $102 | $8 |
| Meadowbank | 40 | 5 | 48 | 138.8 | $6,664 | 16% | $7,890 | 92 | 408 | 500 | 84% | $164 | $13 |
| Gordon 1 | 144 | 15 | 63 | 166.6 | $10,495 | 25% | $13,937 | 164 | 336 | 500 | 75% | $221 | $21 |
| Gordon 2 | 144 | 15 | 78 | 166.6 | $12,994 | 32% | $19,127 | 236 | 264 | 500 | 68% | $245 | $26 |
| Tribute | 82.8 | 6 | 84 | 239.5 | $20,116 | 36% | $31,276 | 277 | 223 | 500 | 64% | $372 | $40 |
| Fisher | 43.2 | 3 | 87 | 249.9 | $21,740 | 37% | $34,740 | 299 | 201 | 500 | 63% | $399 | $43 |
| Bastyan | 79.9 | 5 | 92 | 277.3 | $25,512 | 40% | $42,806 | 339 | 161 | 500 | 60% | $465 | $51 |
| LI-WY-CA | 170 | 9.5 | 101.5 | 310.5 | $31,518 | 46% | $58,243 | 424 | 76 | 500 | 54% | $574 | $63 |
| Cethana | 85 | 4 | 105.5 | 368.8 | $38,903 | 48% | $75,196 | 466 | 34 | 500 | 52% | $713 | $78 |
| Reece 1 | 115.6 | 5 | 110.5 | 401.2 | $44,333 | 51% | $90,815 | 524 | -24 | 500 | 49% | $822 | $89 |
| Reece 2 | 115.6 | 5 | 115.5 | 401.2 | $46,339 | 54% | $100,281 | 582 | -82 | 500 | 46% | $868 | $93 |
| Gordon 3 | 144 | 6 | 121.5 | 416.5 | $50,601 | 57% | $116,793 | 654 | -154 | 500 | 43% | $961 | $101 |
| Trevallyn | 80 | 3.4 | 124.9 | 408.3 | $50,997 | 58% | $121,786 | 694 | -194 | 500 | 42% | $975 | $102 |
| Mackintosh | 79.9 | 3 | 127.9 | 462.2 | $59,111 | 59% | $145,886 | 734 | -234 | 500 | 41% | $1,141 | $118 |
| Tungatinah | 125 | 4.5 | 132.4 | 482 | $63,820 | 61% | $165,486 | 797 | -297 | 500 | 39% | $1,250 | $128 |
| Lemonthyme | 51 | 0.8 | 133.2 | 1106 | $147,353 | 62% | $389,600 | 822 | -322 | 500 | 38% | $2,925 | $295 |
| Poatina 220 | 100 | 1.5 | 134.7 | 1157 | $155,829 | 64% | $427,596 | 872 | -372 | 500 | 36% | $3,174 | $312 |
| Poatina 110 | 200 | 2 | 136.7 | 1735 | $237,215 | 66% | $698,360 | 972 | -472 | 500 | 34% | $5,109 | $474 |
| Devils Gate | 60 | 0.3 | 137 | 3471 | $475,471 | 67% | $1,428,314 | 1002 | -502 | 500 | 33% | $10,426 | $951 |

The calculations are as follows:

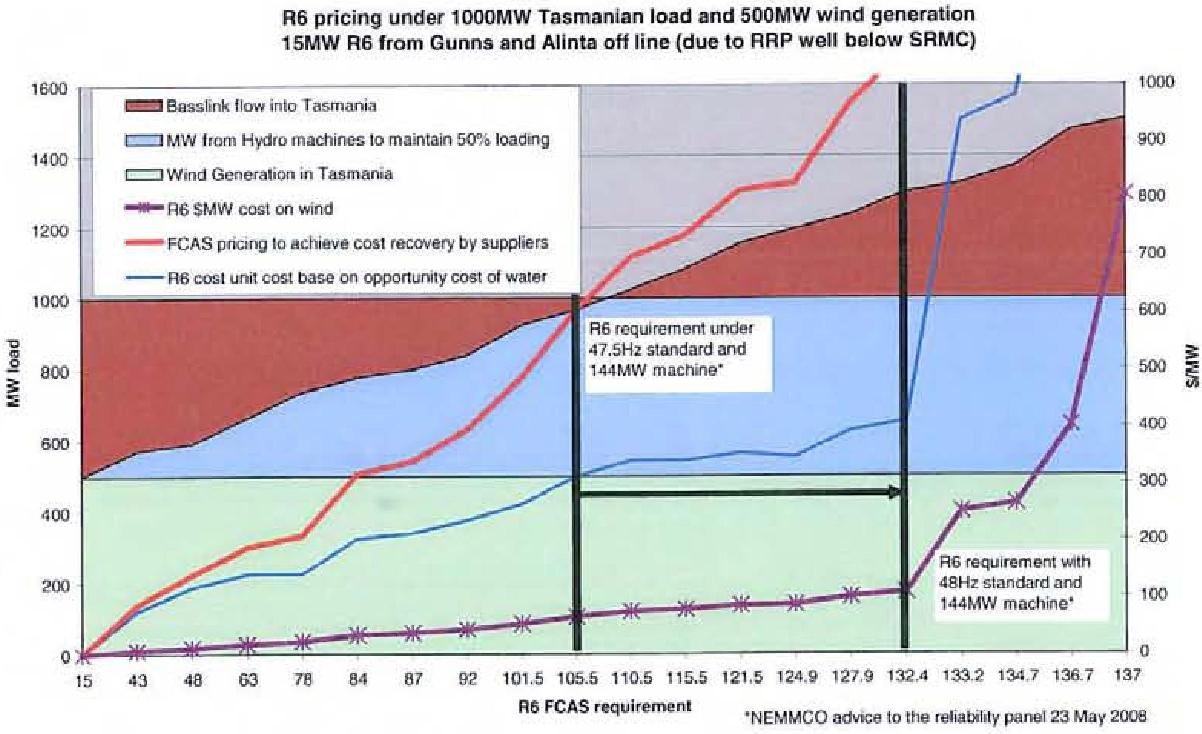
R6 unit cost= (Opportunity cost of Hydro generation/Efficiency @ 50% loading – Tas RRP) * MW capacity of unit / 0.5 / R6 FCAS capability of the unit.

*Total R6 cost*= cost of incremental R6 service * total volume of R6 provided.

*Adjusted R6 price* to account for cost recoverable from R6 FCAS providers = Volume Tas generation/Volume wind generation * R6 unit cost

R6 $/MW cost on wind generation= *Total R6 cost* * total volume of R6 provided / Volume wind generation. i.e. R6 is priced so as to recover the entire cost from the wind generation.

This is represents the following supply curve:




The earnings of wind generation can be calculated as REC revenue + Spot Market minus variable O&M costs. So in this example (with a typical REC revenue of $50), a spot market price of $30 and a typical variable O&M cost of $15 gives a net revenue of $65. So if the contingency FCAS liabilities rise above this level, the wind turbines will be switched off to avoid negative earnings. It can be seen in this example that this occurs once the R6 FCAS requirement exceeds around 102MW.

## Appendix B - Economic considerations for development of combined cycle gas plant in Tasmania

This appendix provides information on the suitability of "multi-machine" combine cycle gas plant that could potentially operate under the existing Tasmanian operating frequency standards with similar economics to a single shaft unit.

This suggestion was made on the basis of the following logic and information:

1. A multi-shaft CCGT is typically combination of one or more open cycle gas turbines and a steam turbine.
2. There are already open cycle gas turbines and steam turbines operating in Tasmania under the existing frequency operating standard.
3. The Gunns submission indicates that a commercially acceptable turbine life can be achieved for a steam turbine operating under the low frequency range of the existing frequency operating standard.
4. Public domain information on combined cycle gas turbines in Australia in recent years indicates a modest difference in cost between single shaft and multi-shaft machines.
5. The ACIL Tasman report on Fuel resource, new entry and generation cost in the NEM does not indicate variation in operation costs between single shaft and multi-shaft machines, neither does it indicate operational cost penalties for operating aero-derivative machines.
6. Aero derivative gas turbines are used in base load applications and marketed in combined cycle configuration by mainstream manufacturers

A question was also raised in the public forum as to whether aero-derivative gas turbines are suitable for base load operation. This is also addressed.

### 1. A multi-shaft CCGT is typically combination of one or more open cycle gas turbines and a steam turbine- refer manufacturers web sites (7),(8)

### 2. There are already open cycle gas turbines and steam turbines operating in Tasmania under the existing frequency operating standard.

There are currently 3 x Pratt & Whitney 38.75MVA FT8 Twin-Pac Gas Turbine Generators (1) at Bell Bay power station which have been able to be connected and operate with the Tasmanian frequency operating standard in place. The Pratt & Whitney website advertises this model as an aero derivative design suitable for combined cycle configurations (8).

There is currently a Rolls Royce Trent 60 60MW unit (9) being installed at Bell Bay power station which presumably will be able to operate within the current Tasmanian frequency operating standard given the advance status of this project. The Rolls Royce web site advertises this model as an aero derivative design suitable for combined cycle configurations (8).

There are currently 2 x 120MW gas thermal (steam) units which have been able to connected and operate with the Tasmanian frequency operating standard in place. These were installed in 1971(1).

**3.The Gunns submission to the Reliability Panel Review of Frequency Operating Standards for Tasmania (the Gunns submission) indicates that a realistic machine life of the turbine can be achieved for the low frequency aspects of the existing frequency operating standard.**

Page 9 of the Gunns submission (10) that indicates:

- Under the existing minimum access standard, the low frequency events would give a 36.4year plant life.
- Under the existing minimum access standard, the high frequency events would give a 3.8year plant life.

So in the context of the discussion as to whether the low frequency portion of the frequency access standard is a problem for the Gunns plant, this suggests that reason life span can be achieved. Application of a typical discount rate to re-blading a steam turbine after 40 years would result in an economic amount that would most likely be insignificant to the current cost-benefit analysis.

**4. Public domain information on combined cycle gas turbines in Australia in recent years indicates a modest difference in cost between single shaft and multi-shaft machines.**

The larger CCGT units recently installed in Australia are listed below:

| Station | MW installed | configuration | Capital cost | $/MW |
|---|---|---|---|---|
| Swanbank E | 385MW (2) | Single shaft CCGT (2) | $300M (2) | $779k |
| Pelican Point | 487MW (3) | 2 of 160MW GT (4)<br>1 of 158MW steam | $420 (3) | $862k |
| Kwinana | 320MW (5) | 1 of 160MW GT (5)<br>1 of 160MW steam | $400M (6) | $830k |

Although this is small data set, it is noted that the two multi-machine installations incurred an extra capital cost of 6.5% and 10.6% over the single shaft installations.

It is suggested that the Reliability Panel should seek expert advice on this matter if these numbers are critical to the cost-benefit analysis.

**5. The ACIL Tasman report on fuel resource, new entry and generation costs in the NEM (ACIL report) does not indicate variation in variable operation and maintenance costs between single-shaft and multi-shaft combined cycle generators, neither does it indicate differential operations and maintenance costs between industrial and aero-derivative gas generators**

The ACIL Report is maintained for National Electricity Market Management Company (NEMMCO) as a key input to the Statement of Opportunity (SOO) and Annual National Transmission Statement (ANTS) processes. As such it is a definitive public domain source on generation plant economics in the NEM. It is consulted on annually, and as such the contents are annually tested in the public domain.

The thermal efficiency, auxiliaries and variable O&M of existing plant and proposed new plant is describe in sections 11 and 12 of the report respectively. Key points to note are:

- The multi-shaft and single shaft combined cycle gas turbines have very similar thermal efficiencies.
- The multi-shaft and single shaft combined cycle gas turbines have similar variable O&M costs.
- The different types and sizes of open cycle gas turbines have similar O&M costs with the exception of the aero-derivative units at Ladbroke Grove and Bell Bay 3 which have markedly low costs. This is presumable due to the reduced number of starts that result from high duty cycle / base load operation of these units.

**6. Aero derivative gas turbines (of the type currently operating in Tasmania) are used in base load applications and marketed in combined cycle configuration by mainstream manufacturers**

Both Rolls Royce (7) and Pratt & Witney (8) advertise their Trent and FT8 Twin-Pac technology respectively as being deployed in combined cycle configuration.

**7. Aero derivative gas turbines are used in base load applications.**

The NEMMCO market management systems show that the aero-derivative LM6000 units at Ladbroke Grove power station operated in base load mode for many years. It is also noted that page 92 of the ACIL reports indicates that these units have a variable O&M cost less than $4 per MWhr, which is better than the majority of gas turbines in the National Electricity Market.

**References**


ACIL report on Fuel resource and generation cost in the NEM
1.http://www.nemmco.com.au/psplanning/410-0090.pdf

Swanbank E
2.http://www.csenergy.com.au/_CMSImages/csenergy/pdfs/pre2005/020901%20SBKEMEDIARELEASE.pdf

Pelican Point
3.http://www.internationalpower.com.au/_modules/Uploader/_uploaderBin/lwalsh/b023ab9aa393078898893b02afe85e06InternationalPowerAustraliaAssetFactSheets.pdf
4.http://www.power.alstom.com/_eLibrary/presentation/upload_22222.pdf

Kwinana
5.http://www.au.alstom.com/home/newsroom/press_archive/36398.EN.php
6.http://www.newgenpower.com.au/files/newgen-a3-brochure.pdf

Aero derivative CCGT
7.http://www.rolls-royce.com/energy/products/powergen/trent/apps.jsp
8.http://www.pw.utc.com/vgn-ext-templating/v/index.jsp?vgnextoid=658e34890cb06110VgnVCM1000004601000aRCRD

Bell Bay
9. http://www.environment.tas.gov.au/_downloads/BBPS-SuppGen_DPEMP_FINAL1.pdf

Gunns submission to the Reliability Panel Review of Frequency Operating Standards for Tasmania
10.http://www.aemc.gov.au/pdfs/reviews/Review%20of%20Frequency%20Operating%20Standards%20for%20Tasmania/Submissions/006%20Gunns%20Limited.pdf