Report ID: TrimD07/:66728

Issue: final F3.0

Date: 10 December 2007

Frequency Standard Development

Final Report to Alinta Power

DOCUMENT INFORMATION

TITLE:	**Frequency standard development final report.**

TRANSEND INFORMATION

TRIM NUMBER	
DATE	**16 May 2008**
REVISION STATUS	**Final F3.0**
TRANSEND CONTACT	**Chandra Kumble(Hill Michael)**
JOB/PROJECT NUMBER	**3134/004**

EXTERNAL PARTY INFORMATION

ORGANISATION	**Alinta Pty Limited**
CONTACT	**Allan Coleman**

Document History and Status

Revision	Prepared by	Reviewed by	Approved by	Date approved	Revision type
F1.1	Prahlad Tilwalli	Chandra Kumble			Contents
F1.2	Prahlad Tilwalli	Chandra Kumble		10 November 2007	Contents-Detailed studies
F1.3	Doug Clarke	Stephen Jarvis		10 December 2007	
F2.0	Prahlad Tilwalli	Chandra Kumble	Chandra Kumble	10 December 2007	Final
F3.0	-	-	Chandra Kumble	16 May 2008	Setting data removed

Distribution of Copies

Revision	Date of distribution	Quantity	Issued to
F1.3	10 December 2007	1	Stephen Jarvis, Doug Clarke, Andrew Halle, Prahlad Tilwalli
F2.0	11 December 2007	1	Stephen Jarvis, Andrew Halley, Allan Coleman (Alinta)
F3.0	16 May 2008	1	As above

Executive Summary

Alinta is building a new power plant at George Town close to the existing Bell Bay power station. This is expected to be progressively commissioned from March 2009-September 2009. The new generation plant will be comprised of an open cycle gas turbine (58 MW) and a combined cycle gas turbines (CCGT – 209 MW) with a total capacity of 267 MW. Alinta has provided Transend with the plant data for assessing its compliance with the National Electricity Rules (NER) requirements. One of the requirements in the NER is that the plant should meet frequency capability requirements in accordance with NER Clauses S5.2.5.3, S5.2.5.5 and S5.2.5.11. On reviewing the data, Transend has found that the frequency capability of the plant does not meet the minimum access standard requirements of the NER with the current Tasmanian Frequency Standard[1].

However, based on a request from Alinta, Transend has investigated issues surrounding changes to the current frequency operating standards that may be required to accommodate the proposed Alinta generation characteristics. In investigating a suitable frequency standard, issues surrounding changes to the existing Under Frequency Load Shedding Scheme (UFLSS), Over Frequency Generator Shedding Scheme (OFGSS) and Frequency Control System Protection Scheme (FCSPS) are also investigated using a high level inertia based model. Following the establishment of a proposed frequency standard, further studies will be undertaken to examine Reserve Management Issues resulting from the new standard and in particular the size of the proposed CCGT from Alinta.

This final report summarises findings from the studies associated with establishing a proposed frequency standard to accommodate the CCGT characteristics. The findings are:

a. The proposed changes to the frequency standard to accommodate the CCGT and other thermal units are feasible with some changes to the reserve requirements.

b. The Standard will require physical changes to settings for the UFLS in that a shift upwards by 0.5 hz will be required.

c. The reserve requirements based on the present largest contingency in Tasmania of 144 MW may need to increase by 64 MW.

d. Discrimination exists between FCSPS and OFGSS.

e. To achieve discrimination between FCSPS and UFLSS $\Delta f/\Delta t$ (Average frequency over 300 second period) setting in the UFLSS would have to be increased to 1.2 Hz, but the rest of the settings remain as determined in the high level studies.

f. A secondary delay time will need to be set for blocks 4 to 7 to ensure that after they time out loads will be tripped to return the frequency to the regulation band under some unusual system conditions. ***.*** ***(<u>note:</u> This is not a new requirement as under some situations this will be needed even now, when load generation balance are very close after loss of generation and some load shedding)***

[1] AEMC-Reliability Panel-Tasmanian Reliability and Frequency Standard-Determination-28 May 2006

g. Increasing the generator contingency to 208 MW shows no particular issues with new standard on the basis that sufficient reserve is available.

h. The presence of the CCGT and other thermal units tends to increase the overall inertia and thus rate of change of frequency decreases which reduces FCAS requirement slightly.

i. The presence of the CCGT also adds significant FCAS lowering capability and will assist in reducing FCSPS generation shedding quantity in many cases (assuming that this capability is made available to the FCAS markets).

j. The reserve procurements and options are not considered at this stage, but studies shows one option of market procurement may be feasible, subject to further evaluations of other options.

k. With adequate FCAS raise set to cover loss of the largest unit in the system, no additional load was required for arming to cover tripping of Basslink in 3 out of 4 cases. In one case however about 15 MW more was required. More scenarios would have to be analysed to get a better picture.

l. While Basslink is exporting, with Thermal units providing significant FCAS lower capability, it would not be necessary to arm any more generators to maintain frequency below 52 Hz for Basslink tripping. This is dependent on Thermal generators confirming that the units are really capable of fast lower service.

m. Actual FCAS determined from studies is more than the estimated FCAS using FCAS trapeziums provided by hydro. In estimating FCAS requirement only load relief due to frequency is considered but not inertia effect.

n. If adequate FCAS is not procured to cover outage of largest unit, under frequency load shedding occurs as expected.

o. Under multiple contingencies, over-frequency is a problem with thermal sets connected as frequency goes above 52 Hz with the present operating arrangements thereby breaching the proposed frequency standard. Also CCGT would trip which may cause UFLSS to shed load, thereby not complying with NER requirement.

p. CCGT plants and other thermal plants would have to be included in OFGSS and co-ordinated to shed generation in a planned manner. In order to achieve co-ordination between CCGT and thermal plants to prevent all these units tripping simultaneously causing severe load shedding, these plants would have capability to stay connected above 52 Hz at least for a few seconds or other alternative solutions would have to be explored to resolve the over frequency issue

The next phase of this work involves detailed modelling of the Tasmanian system including Basslink to address the reserve management issues resulting from changes in the standard. The next stages are:

- Issue a scope document and methodology to be followed for conducting Reserve management technical studies**. (by 15 January 08).**
- Final report on frequency Standard Development **(by 10 April 08)** including recommendations.
- Review the findings with Alinta and agree on the next stage of work: Reserve Management Market impact and economic analysis studies.

.

Contents

-

ACRONYMS

AEMC	Australian Energy Market Commission
AER	Australian Energy Regulator
CCGT	Combined Cycle Gas Turbine
FCAS	Frequency Control Ancillary Services
FCSPS	Frequency Control System Protection Scheme
Hz	Hertz (cycles per second)
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
NER	National Electricity Rules
NSP	Network Service Provider
MW	Mega Watt (1000 Watts)
MVA	Mega Volt Amp (1000 Volt Amps)
OCGT	Open Cycle Gas Turbine
OFGSS	Over-Frequency Generator Shedding Scheme
PSSE	Power System Simulator for Engineering (software tool)
UFLSS	Under-Frequency Load Shedding Scheme

1. INTRODUCTION

Alinta is building a new power plant at George Town close to the existing Bell Bay power station. This is expected to be progressively commissioned from March 2009- September 2009. The new plant would comprise of an open cycle gas turbine (58 MW) and a combined cycle gas turbines (CCGT – 209 MW) with a total capacity of 267 MW. Alinta has provided Transend with the plant data for assessing its compliance with the National Electricity Rules (NER) requirements. One of the requirements in the NER is that the plant should meet frequency capability requirements in accordance with the NER Clauses S5.2.5.3, S5.2.5.5, and S5.2.5.11. On reviewing the data it has been found that the frequency capability of the plant, may not meet the minimum access standard requirements of the NER with the current Tasmanian Frequency Standard[2].

The Tasmanian Frequency Standard is different to the rest of the National Electricity Market (NEM). The Australian Energy Management Commission (AEMC) in their determination in May 2006, on the Tasmanian frequency standard stated that an additional review will be undertaken within the next twelve months to further align the Tasmanian Frequency standard with the NEM standards based on a full cost benefit analysis.

In order to allow the Alinta power plant to be connected, the current frequency standard will have to be modified or Alinta will have to seek derogation. In order to understand the issues and their implications to the proposal, Alinta has requested Transend to investigate issues associated with developing a modified frequency standard that is suitable for the characteristics of their plant. In particular this work is intended to provide sufficient information for seeking derogation or to influence the future direction of the Frequency Standard Review by the AEMC. A detailed scope for the study and agreed deliverables are given in Appendix A.

This final report covers Phases 1, 2 and 3 of the scope, which is the identification of a proposed Frequency Standard based on both high level and detailed studies. In investigating a suitable standard the following technical issues have been considered as relevant and are therefore taken into account in the analysis. In particular, the analysis has made the following assumptions on existing schemes:

- Existing Under Frequency Load Shedding Scheme (UFLSS):- The number of blocks is unchanged but the size of load blocks could be altered.
- Over Frequency Generation Shedding Scheme (OFGSS):- The settings are allowed to be altered.

[2] AEMC-Reliability Panel-Tasmanian Reliability and Frequency Standard-Determination-28 May 2006

- Frequency Control System Protection Scheme (FCSPS) to manage frequency for Basslink contingencies: - It is assumed that the existing settings are to be maintained, however, the detailed analysis may indicate that the FCSPS needs to be re-designed.
- Frequency control ancillary services (FCAS):- The existing approach is maintained but new quantities are to be determined on the basis of the largest single contingency risk.

This investigation scope does not cover issues associated with the practical implementation time table, costs associated with delivering the changes and the allocation of costs. Further, the scope does not cover issues associated with changing the existing contract arrangements, time table and costs. The Reserve Management issues will be dealt with as part of later stages of the investigation.

2. NATIONAL ELECTRICITY RULES REQUIREMENTS OF GENERATORS FOR FREQUENCY

The National Electricity Rules (NER) requirements for generators requiring access to the NEM are resolved through access negotiations. They relate to the setting of acceptable performance standards in the access negotiation framework. The performance standards are normally allowed to be negotiated between a minimum standard and an automatic standard, if the automatic access standard cannot be achieved. In a number of the rules, the minimum access standard requirements can be set at a higher level than that outlined in the NER by NEMMCO on advice to the NSP of any increased performance requirements required by them for power system security and reliability.

The NER requirements for generators related to frequency are mainly expressed in the following clauses:

- S5.2.5.3 – Generating unit response to frequency disturbances;
- S5.2.5.5 – Generating system response to disturbances following contingency events; and
- S5.2.5.11 – Frequency control.

The definition of "continuous uninterrupted operation" given in the glossary is also relevant to the understanding of performance requirements.

In summary, S5.2.5.3 requires, as a minimum, that a generator remains in continuous uninterrupted operation for various frequency bands for particular time periods, provided that the rate of change of frequency (measured for 1 second in the minimum access standard) remains within -1 to +1 Hz/second. If the rate of change of frequency lies outside the range given above, then there is no requirement to remain in continuous uninterrupted operation for the bands and times given in clause S5.2.5.3. It is unclear whether a generator that could not meet the minimum access standard in Tasmania with regard to maintaining continuous uninterrupted operation for the frequency bands can obtain connection approval because the frequency rates of change to get the power system frequency to extreme levels would usually exceed the levels that set the minimum access standard. This would need to be explored in the access negotiations.

One of the clauses in S5.2.5.3 requires a negotiated access agreement to meet three requirements which may make it more difficult for parties to reach agreement on interpretations that the Alinta plant meets the minimum access standards considering the rates of change of frequencies likely to be seen in Tasmania. This discussion needs to be carried out as part of the access negotiations.

In summary, S5.2.5.5 requires at a minimum that a generator remains in continuous uninterrupted operation for a disturbance that is basically a credible contingency. Under some circumstances, where the disturbance causes an over-frequency, then with agreement the generator can trip provided that the total reduction in generation due to the disturbance does not exceed 100 MW. In Tasmania there may already be more than 100 MW of generation (pre-dating the new rules requirement) that could be lost to disturbances which result in significant levels of rate of change of frequency and/or deviations in frequency to the bounds of the current frequency standard. That is the ability to trip for credible contingencies causing over frequency may not be available to Alinta both because of its size and also because plant other than Alinta's could trip from the disturbance.

In summary, S5.2.5.11 as a minimum requires that a generator under relatively stable input energy must not increase active power transfer to the power system for a rise in system frequency; and must not decrease output by more than 2% per Hz in response to a fall in frequency.

The Rules mentioned above have recently come into effect in the NER and their application particularly with respect to Tasmania has not been tested. There is the possibility of some different interpretations to these rules, particularly by different entities involved in the connection access negotiations.

If the frequency standards in Tasmania were changed such that an intending generator could meet the minimum access standard (particularly in S5.2.5.3) without the need to rely on any frequency rate of change interpretations, then there is less uncertainty about the generator gaining an agreed performance standard for frequency performance.

The rest of this report looks at whether the Tasmanian frequency standard could be changed, to a level that allowed the Alinta generator to meet the NER requirements for frequency, and whether that frequency standard would allow the other systems required within the NEM for managing frequency to be acceptably re-designed.

3. COMPARISON OF FREQUENCY CAPABILITY OF ALINTA WITH NER REQUIREMENTS

The characteristics of the CCGT were sourced from the data supplied by Alinta as part of its connection application. It has been assumed that all future CCGTs in the study period will have similar characteristics. The CCGT frequency characteristics assumed are given in Table 3.1 below.

Required capability based on Current Standard (Clause S5.2.5.3)		Combined cycle plant				Compliant Yes/No
Automatic	Minimum	Gas Turbine Generator (GTG)		Steam Turbine Generator (STG)	Combined Capability	
49 - 51 Hz indefinitely	49.85 – 50.15 indefinitely (a)(4)	47.5 – 52 Hz indefinitely		47 – 52.7 Hz indefinitely	47.5 – 52 Hz indefinitely	v YES
47.5 – 49 Hz for 8 minutes	47.5 – 49.85 Hz for 8 minutes					v YES
46 – 47.5 Hz for 2 minutes	46 – 47.5 Hz for 9 sec (a)(1)	47 – 47.5 Hz for 15 sec Trip = 47 Hz with 2 sec delay. (GT load runs back to 20 MW as soon as the frequency falls to less than 47 Hz) Trip = 46 Hz instantaneously		46.9 – 47 Hz (15 min accumulated). 46.8 -46.9 Hz (1 min accumulated). Trip setting data not provided Trip = 46,8 Hz instantaneously	47 – 47.5 Hz for 15 sec Trip = 47 Hz with 2 sec delay. (GT load runs back to 20 MW as soon as the frequency falls to less than 47 Hz) 46.9 – 47 Hz (15 min accumulated). 46.8 -46.9 Hz (1 min accumulated). Relay setting data not provided Trip = 46,8 Hz instantaneously	X NO
53 – 51 Hz for 8 minutes	50.15 – 53 for 8 minutes (a)(5)	Trips > 52 Hz with 0.1 sec delay			Trips > 52 Hz with 0.1 sec delay	X NO
60 - 53 Hz for 2 minutes	55 - 53 Hz for 9 sec (a)(5)					

Table 3-1 Comparison of Alinta Generators Frequency Capability with AEMC Frequency Standard for Tasmania

This table presents the current NER requirements and the area of non compliance of Alinta plant is highlighted in grey to assist in determining the degree of non compliance and as a guide to finding appropriate solutions.

In comparing the operating frequency capability of Alinta's CCGT plant with AEMC frequency standard requirements for Tasmania[2] the following observations are made:

- Automatic access standard requires, in the lower frequency range, the generator to stay connected when the frequency is in the range of 46 to 47.5 Hz for 8 minutes, but the plant trips instantaneously at 46 Hz and can only stay connected in the range of 47 to 47.5 Hz for 15 seconds. The plant is not capable of complying with the Minimum access standard which requires plant to stay connected for 9 sec in the frequency range of 46 to 47.5 Hz. ***It is concluded the plant while complying with the mainland frequency standards does not satisfy Tasmanian frequency minimum access standard at the lower frequency range. (Ignoring the rate of change of frequency rider).***
- Automatic access standard requires, in the higher frequency range, the generator to stay connected in the range of 51 to 53 Hz for 8 minutes and 51 to 55 Hz for 2 minutes, but the plant trips for frequencies greater than 52 Hz with a delay of 0.1 seconds. The minimum access standard requires generators to stay connected in the range of 50.15 to 53 Hz for 8 minutes and 53 to 55 Hz for 9 seconds. The plant does not comply with the minimum access standard. ***It is concluded the CCGT plant while meeting the Mainland frequency operating standard it does not satisfy the minimum access standard requirements of Tasmanian operating standards. (Ignoring the rate of change of frequency rider).***
- NER also requires plant to comply with frequency capability in accordance with clause S5.2.5.11: This clause requires plant output for a fall in frequencies, to increase its output in the automatic standard and decrease by not more than 2% per Hz for the minimum access standard . ***Alinta has not provided this information yet.***

Thus there are many aspects of the NER which needs to be compressed tighter to facilitate CCGT capability with respect to Tasmanian operating standard, while recognising that the plant can meet the mainland frequency standards. .

4. REQUIRED FREQUENCY STANDARD FOR CONNECTING ALINTA

Based on the plant characteristics, the required standard to enable CCGT's to be connected in Tasmania is *proposed as* in table 4-1. The table also presents the aspects of the standard which need to be changed (shown as bold) and the corresponding values from current standards are shown within brackets.

Condition	**Containment**	**Stabilisation**	**Recovery**
Interconnected Operation			
No contingency or load event	49.75 to 50.25 Hz, 49.85 to 50.15 Hz 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Load event	49.0 to 51.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Generation event	**48.0** to 51.0 Hz (47.5 to 51.0 Hz)	49.85 to 50.15 Hz within 5 minutes	
Network event	**48.0** to **52.0** Hz (47.5 to 53.0 Hz)	49.0 to 51.0 Hz within 1 min	49.85 to 50.15 Hz within 5 min
Separation event	**47.0** to 55.0 Hz (46.0 to 55.0 Hz) With thermal units allowed to trip at 52 Hz	**48.0** to 51.0 Hz within 2 min (47.0 to 51.0) Hz	49.85 to 50.15 Hz within 10 min
Multiple contingency event	**47.0** to 55.0 Hz (46.0 to 55.0 Hz) With thermal units allowed to trip at 52 Hz	48.0 Hz to 51.0 Hz within 2 min	49.85 to 50.15 Hz within 10 min
Islanded Operation			
No contingency or load event	49.0 51.0 Hz		
Load event	49.0 to 51.0 Hz	49.0 to 51.0 Hz within 10 min	
Generation event	**48.0** to 51.0 Hz (47.5 to 51.0 Hz)	49.0 to 51.0 Hz within 5 min	
Network event	**48.0** to **52.0** Hz (47.5 to 53.0 Hz)	49.0 to 51.0 Hz within 1 min	49.85 to 50.15 Hz within 5 min
Separation event	**47.0** to **55.0** Hz (46.0 to 60.0 Hz) With thermal units allowed to trip at 52 Hz	48.0 Hz to 51.0 Hz within 2 min	49.85 to 50.15 Hz within 10 min
Multiple contingency event	**47.0** to **55** Hz (46.0 to 55.0 Hz) With thermal units allowed to trip at 52 Hz	48.0 Hz to 51.0 Hz within 2 min	49.85 to 50.15 Hz within 10 min

Table 4-4-1 Proposed Frequency Standard for connecting CCGT

Note: Changes from the current Tasmanian standards are shown in bold letters. (Current Tasmanian standards are shown within brackets)

It can be seen from the Table 4.1 that the changes are mainly in the containment band and one change in the stabilisation band. The changes are:

- *Generator event* – the lower frequency limit in the containment band is required to be changed to **48 Hz** from the current standard of 47.5 Hz for interconnected operation and islanded operation. Also in the stabilisation band the lower frequency limit is changed to **48 Hz** from 47.5 Hz. Thus 0.5 Hz increase in the bottom frequency for a generator event will be required.

- *Network event* – the containment band is changed to **48.0 Hz to 52.0 Hz** from the current standard of 47.5 Hz to 53.0 Hz. Under network event the lower frequency need to be increased by 0.5 Hz, while the upper frequency needs to be lowered by 1 Hz.
- *Separation event and multiple contingency events* – the containment band is required to be changed to **47 Hz to 55 Hz** from the current standard of 46.0 Hz to 55. 0 Hz. This is based on the assumption that thermal plant can be added to the OFGSS to trip at 52 Hz. If this is not possible under the NER, setting an upper end to these bands will be very difficult. (See later).

5. INTERNATIONAL COMPARISON OF THE REQUIRED FREQUENCY STANDARD

In order to assess the requirements against other systems around the world a survey of the standards for the following countries was made:

- New Zealand;
- Ireland; and
- UK (national Grid)

Descriptions of the standards in the above countries are discussed briefly.

5.1 NEW ZEALAND[3]

The New Zealand system is comparable to the Tasmanian system and New Zealand also had a frequency standard similar to the current Tasmanian Frequency standard before the advent of CCGT plant. The standard was modified to allow the more fuel efficient CCGT plants to be connected to the grid. The current New Zealand grid code stipulates that plant should stay connected, in the lower frequency range above 47.5 Hz indefinitely and between 47.5 Hz and 47 Hz, the code specifies an envelope which is defined as under:

- At 47.5 Hz for 120 seconds
- At 47.3 Hz for 20 seconds
- At 47.1 Hz for 5 seconds
- At 47.0 Hz for 0.1 seconds

The duration for any frequency within the bands is interpolated.

The code is quite onerous for CCGT in that it requires them to operate between 47.0 Hz to 47.5 Hz band albeit for graded period of operation between 0.1 second at 47Hz to 120 seconds at 47.5 Hz.

The code also requires the CCGT plant, at a minimum, to sustain pre-disturbance output. In other words the plant can not reduce its output when the frequency goes down.

The standard has also set a limit on frequencies above 50 Hz in two parts: - The North Island frequency should not exceed **52 Hz at any time**, while the South Island frequency should not exceed **55 Hz at any time**.

[3] http://www.electricitycommission.govt.nz/pdfs/rulesandregs/rules/rulespdf/PartC-27Sep07.pdf

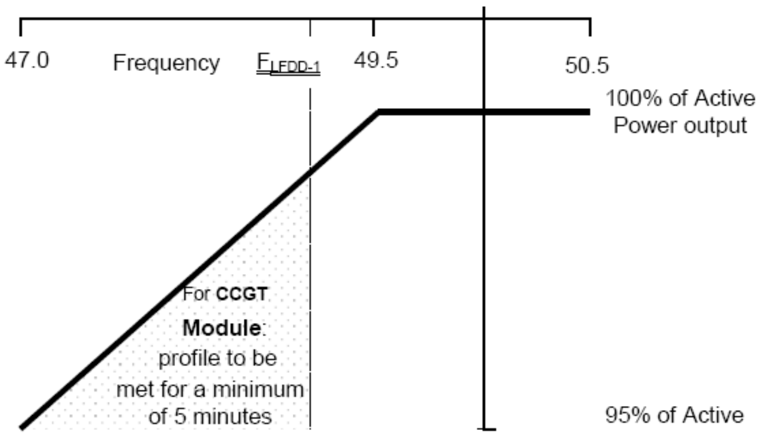
Note: The South Island frequency should not fall below **45 Hz at any time and stay no more than 30 seconds between 47.0 Hz to 45 Hz**. This standard is aimed at Hydro plant as there are no CCGTs in South Island.

Details of the Rules could be obtained from the website.

5.2 IRELAND (EIRE)[4]

The code specifies that generating units shall be capable of satisfactory operation at any frequency within the range of 47 Hz to 52 Hz unless Northern Island Electricity (NIE) has agreed to the use of any frequency level relays which will trip the Generating Unit within this Frequency range. The code does not specify any specific time limit in the region between 47.5 Hz and 47 Hz.

Eire grid code also requires plant to maintain plant output as in the National Grid Code (NGC) as shown in Figure 5.1



5.3 UK (NATIONAL GRID)[5]

The NGC requires plant to stay connected from 47.5 Hz to 52 Hz indefinitely and from 47.5 Hz to 47.0 Hz to stay connected for 20 secs only.

NGC requires plant to maintain active power output in the range of 50.5 Hz to 49.5 Hz and to maintain its output at a level not lower than determined by the relationship shown in Figure 5.1 Plant output at low frequency for system frequency changes within the range 49.5 Hz to 47 Hz such that if the frequency drops to 47 Hz the active power output does not decrease by more than by 5%.

[4] http://www.soni.ltd.uk/upload/6-CONNECTION%20CONDITIONS.doc

[5] http://www.nationalgrid.com/NR/rdonlyres/83FD31D3-0F0E-4B20-8345-9636E0093453/20007/CC_i3r22_entire.pdf

Figure 5.1 Plant output at low frequency

5.4 SUMMARY CONCLUSION OF INTERNATIONAL COMPARISON

It is concluded from the brief survey of standards that the rules elsewhere in the world are more onerous than the one suggested for connecting Alinta generators into Tasmania with the characteristics given.

6. IMPACT OF CHANGES IN FREQUENCY STANDARD ON OTHER SCHEMES

Any changes to the frequency standard will need to be reviewed in light of its impact on other schemes. The AEMC and the Reliability Panel have indicated that they will conduct a cost/ benefit analysis of any proposed changes to the Tasmanian frequency standard. The schemes that will be affected by the changes in frequency standard are:

- Under Frequency Load Shedding Scheme (UFLSS)
- Over Frequency Generation Shedding Scheme (OFGSS)
- Frequency Control System Protection Scheme (FCSPS) to manage frequency for Basslink tripping
- Frequency controlled ancillary service management:-The changes in frequency standard will have a major impact on the ancillary service quantity. In particular Frequency Control Ancillary Services (FCAS) is a major issue in Tasmania and compressing the frequency operating band will require significantly more FCAS for the single credible contingency band.
- Large penetration of wind generation: - The changes in the frequency standard will present a number of technical issues in relation to the future mix of generation and in particular penetration of large amounts of wind generation in future years.

This section does not deal with the economic benefits and cost of changing the frequency standard, but looks at whether it is likely to be possible to re-design schemes to meet the proposed frequency standard.

The technical issues associated with each of the above will be discussed in detail in the following sections.

6.1 IMPACT ON EXISTING UNDER FREQUENCY LOAD SHEDDING SCHEME (UFLSS)

An UFLSS scheme has been installed and is in operation in Tasmania to institute controlled load shedding for un-planned and extreme events that result in a drop in frequencies below the levels set in the generator and network event bands. Further the scheme has been designed to act as a back up to the Frequency Control Protection System Protection Scheme (FCSPS) designed as part of the Basslink connection to the mainland as the link capacity is in excess of the largest generator in Tasmania. The FCSPS will trip loads to prevent the frequency falling below what is allowed in the NER for a generator / network contingent event, to cover for the loss of Basslink when it is importing.

The UFLSS scheme is also required to limit the frequency decline to below the NER separation event requirements when Basslink is out of service or islanding occurs within Tasmania. This section discusses the present settings, and the changes to the settings that are required for a frequency standard as per CCGT characteristics outlined in section 3 and the associated issues which need to be addressed.

6.1.1 PRESENT UFLSS SCHEME

The Tasmanian Frequency standard for a multiple contingent event resulting in the loss of a large block of generation is maintained by load shedding. The present load shedding scheme is designed to shed load between 46 Hz and 47.5 Hz according to the current frequency standards. The present load shedding has 7 blocks with settings as per given in Table 6.1. The table also shows the load available for shedding during winter peak period. The system frequency is maintained by shedding load between the minimum frequency set for a Generator contingent event / Network event (47.5 Hz) and a multiple contingent event (46 Hz). Therefore the existing UFLSS will require to be compressed to accommodate the suggested frequency standards for the CCGT.

Block No	f + Df/Dt Relay			f relay
	pick-up Frequency Hz	freq deviation Hz	measuring time Sec	pick-up Frequency Hz
1	48.5	0.30	0.34	47.40
2	48.2	0.30	0.34	47.20
3	0.0	0.00	0.00	47.00
4	0.0	0.00	0.00	46.80
5	0.0	0.00	0.00	46.70
6	0.0	0.00	0.00	46.50
7	0.0	0.00	0.00	46.10

Note: blocks 4 to 7 would have to have secondary trip setting with 10 sec delay to ensure that frequency does not stay in the band 47 to 47.5 Hz for more than 20 sec

Table 6.1 Current UFLSS setting

Even though the Tasmanian Frequency standard allows the frequency to rebound up to 55 Hz for multiple contingency events, frequency is maintained below 52 Hz following operation of the UFLSS scheme to prevent further generators tripping (which have relays set to trip at frequencies from 52 Hz upward) on frequency rebound after load shedding. So, the block sizes in the UFLSS are such that over shedding does not cause frequency to reach levels that would trip further generating units.

6.1.1.1 Issues in changing the UFLSS settings

There are a few issues which need to be considered before changes could be made to the UFLSS. They are:

1. The proposed new settings should have sufficient discrimination between various blocks to allow practical implementation.
2. The changes in the block size should not result in frequency overshoot causing further generators to trip.

The above issues will be investigated in the studies to assess the adequacy of the proposed settings.

6.2 IMPACT ON EXISTING OVER FREQUENCY GENERATION SHEDDING SCHEME (OFGSS)

An OFGSS scheme was installed in the Transend system as part of Basslink interconnection to the mainland to act as a back up to the Frequency Control Protection System Protection Scheme (FCSPS) which will trip generators to limit the over frequency when Basslink trips while exporting and, in addition, to limit over-frequency when islanding occurs within Tasmania, allowing the islanding frequency standards to be achieved.

6.2.1 PRESENT OFGSS SETTINGS

The current settings for the OFGSS are shown in Table 6.3. The current settings allow the co-ordinated tripping of generators between 52.8 Hz and 58.0 Hz to control severe over frequency events in various sub-regions of the Tasmanian network.

Generator	Frequency Supervised Average Rate of Change of Frequency (f + ?f/?t)		
	F (Hz)	?f (Hz)	?t (sec)
A – Sub-region A	52.8	+ 0.2	0.40
B – Sub-region A	53.4	+ 0.2	0.40
C – Sub-region A	54.0	+ 0.2	0.40
D – Sub-region A	54.4	+ 0.2	0.40
E – Sub-region A	57.0	+ 0.2	0.40
F – Sub-region A	58.0	+ 0.2	0.40
G – Sub-region B	52.8	+ 0.2	0.40
H – Sub-region B	54.0	+ 0.2	0.40

Table 6.3 Current OFGSS Settings

6.2.2 TRIPPING OF UNITS AND OFGSS

Emergency control action undertaken by other generators during high frequency events has been taken into account when designing the settings of the OFGSS.

6.2.3 ISSUES IN CHANGING OFGSS SETTINGS

The Alinta's CCGT characteristics are such that it will require the plant to be included as part of the OFGSS scheme. Further the CCGT will need to be set to trip at 52 Hz and its settings need to be coordinated with the OFGSS requirements. The key issue in determining whether the re-designed OFGSS will be acceptable is whether it meets the NER requirements. It would appear possible to re-design the scheme to ensure that it maintains frequency within the proposed separation/ multiple contingency bands for most readily foreseeable events. However the critical issue is whether the re-designed OFGSS can meet the requirement of clause S5.2.5.3 negotiated access, which indicates that where a generator trips on over-frequency (with the agreement of the NSP & NEMMCO) the frequency would be unlikely to fall below the lower bound of the operational frequency tolerance band as a result of over frequency tripping. For the proposed frequency standards, the frequency would be required to remain above 48.0 Hz following the tripping of the Alinta generating units at 52.0 Hz. Detailed analysis will be required to ensure that this condition is met for all reasonably foreseeable scenarios.

6.3 IMPACT ON FREQUENCY CONTROL SYSTEM PROTECTION SCHEME (FCSPS)

If the Tasmanian frequency standards are changed to require the network event in the frequency containment band of 48 Hz to 52 Hz, then for a Basslink interconnector trip during import, the frequency would have to be contained to 48 Hz. Further for a Basslink interconnector trip during export, the frequency would have to be contained to 52 Hz. This is currently being achieved by a combination of tripping Basslink contracted load under import conditions and Frequency Controlled Ancillary Service (FCAS) raise service procured from the market.

Under Basslink export conditions a combination of generator tripping and FCAS lower service procured in the market is used. The generator tripping is currently achieved by arming Hydro Tasmania generators for tripping during Basslink export and loss of Basslink.

6.3.1 ISSUES IN CHANGING FCSPS SETTINGS

There are a number of issues which need to be investigated in developing a standard to accommodate the proposed CCGT characteristics. They are:

FCAS PROCUREMENT ISSUES

The proposed frequency standard will compress the frequency bands used for procuring FCAS and supplemented by the Basslink FCSPS on the loss of Basslink. As the Basslink FCSPS scheme optimises the flow on the link by use of contracted load shedding (during import)/generator tripping(during export) with FCAS raise/lower services procured through the market, if the FCSPS settings were to remain at the current levels, tripping the current load or generators, then the amount of FCAS required would need increase to meet the proposed frequency standard. As an alternative, re-designing the FCSPS to increase the contracted load and generator shedding then perhaps the FCAS service will remain the same. **As this is a reserve management issue, this will be investigated in the next phase of the investigation and is not discussed here.**

The current FCSPS may be able to maintain the frequency to above the proposed frequency of 48.0 Hz for the loss of Basslink on import. This will need to be verified in the detailed studies and will depend to some extent on the margins required in the system models to ensure that they correctly model Tasmanian system frequency behaviour.

The current Basslink FCSPS design will not allow the proposed frequency of 52.0 Hz to be achieved following the loss of Basslink on export. The Basslink FCSPS will need to be re-designed to meet this change in the upper frequency level. This may require additional generation to be tripped by the FCSPS for loss of Basslink on export.

UFLSS ISSUES

On the assumption the FCSPS operates to contain the frequency to above 48 Hz following a Basslink trip (as a network event) under import conditions, the UFLSS scheme needs to be designed to ensure that it will not operate for the tripping of Basslink during import conditions. The UFLSS will need to be designed to ensure that there is enough discrimination (margin) between the Basslink FCSPS design operating time and the UFLSS scheme operation.

OFGSS ISSUES

On the assumption the FCSPS operates to contain the frequency above 52 Hz (for a network event, upper frequency limit) following a Basslink trip during export, the OFGSS will need to be designed to ensure that there is enough discrimination (margin) between the Basslink FCSPS design operating time and the OFGSS scheme operation. However, Alinta’s plant may have to be a part of both OFGSS and FCSPS scheme and this issue needs to be addressed in the detailed design to be conducted later in the project.

The high level studies in the next section will address the above issues to assess if it is feasible to design a frequency standard to accommodate the CCGT characteristics.

7. HIGH LEVEL STUDIES CONFIRMING ADEQUACY OF PROPOSED SETTINGS

7.1 MODIFIED UFLSS

With the generator event / network event frequency band required to be respectively set at 48 Hz and the separation / multiple contingency band set at 47 Hz to accommodate the CCGT plant, the current UFLSS would have to be modified to shed load within a frequency band of 47 Hz to 48 Hz, against the current range of 46 Hz to 47.5 Hz. So the frequency band available for the under frequency load shedding scheme decreases from 1.5 Hz to 1 Hz. Essentially a further reduction will be required as well as the UFLSS is required to operate at a higher frequency than what is currently in place.

To design a UFLSS the following options are available:

1. Change the frequency settings, block size remains as per current;
2. Change both the frequency settings and block size

The approach adopted for calculating new UFLSS settings is similar to that adopted in determining the original settings. Appendix C sets out a design criteria and the design calculation for determining frequency settings. On observation of the proposed frequency standard, the only changes required in the settings are the Δf/Δt pick-up frequency setting and frequency settings with the block size remaining unchanged (**Option 2 above**). This is expected to result in a minimum of changes to the current UFLSS design and is considered as probably the best way of achieving the desired requirements. The settings in Table 6.1 have been modified by changing the frequency pick up point from what is currently in place. This approach will result in the possible settings to be as shown in Table 7.1

Block No	Δf/Δt: pick-up Frequency (Hz)	Δf/Δt: freq deviation (Hz)	Δf/Δt: measuring time (sec)	f: pick-up Frequency (Hz)
1	49.0	0.30	0.34	47.95
2	48.8	0.30	0.34	47.75
3	0.0	0.00	0.00	47.55
4	0.0	0.00	0.00	47.35
5	0.0	0.00	0.00	47.25
6	0.0	0.00	0.00	47.15
7	0.0	0.00	0.00	47.05

Table 7.1 Modified UFLSS settings

A high level study was then carried out to confirm if the issues raised in section 6 are addressed. In particular the high level studies are intended to assess whether the proposed settings will achieve appropriate discrimination:

- To limit the frequency overshoot for large load loss; and

- To provide enough margins to act as back up for failed FCSPS operation for loss of Basslink (during import).

7.1.1 MODELLING APPROACH

The philosophy behind the high level modelling is to identify those aspects that critically influence the frequency change and the rate at which it will fall following a critical event. For the Tasmanian system, either for loss of a large amount of generation or loss of Basslink under high import, the initial rate of change of frequency would be very high for the Tasmanian system as it is dependent only on **system inertia**, which is low for the Tasmanian system. As a result frequency drops very rapidly. During this period the governors are not effective in pulling the system frequency up as their response is too slow.

The only mechanism available for limiting frequency deviation in the initial few seconds of such an event is by instituting load shedding and to a certain extend load self regulation. In the high level studies, only the inertia effect and load shedding are modelled. Simulations were carried out under various system loads to calculate the resulting frequency deviation from the initial 50 Hz value. The calculations are done using a spreadsheet.

In studies the effect of the Basslink frequency controller is ignored because in the worst case scenario of Basslink importing at its limit, frequency controller would be ineffective in providing any FCAS for generator contingencies as it is assumed there is no head room on Basslink. This is the most onerous condition and considered as a boundary condition.

Either a loss of a large block of generation or loss of Basslink under high import is the critical events that would cause the rate of change of frequency to be very high. This is mainly due to the size of the system and the resulting total inertia of the system. The initial rate of change of frequency is dependent **on the total system inertia immediately following an event.** Further the rate of change of frequency is so high that the resulting time available for load shedding is likely to be less than a couple of seconds. During this period hydro generator governors are not effective in pulling the system frequency up as their response time is much slower. The only mechanism available for limiting frequency deviation during the initial few seconds of such an event is by instituting a fast load shedding scheme.

Therefore in the high level studies the inertia imbalance is modelled to assess whether there is an appropriate balance between the quantity of load shedding and the resulting frequency overshoot that is achieved. Therefore a simple energy balance equation was set up to represent a relationship between machine (system) inertia with load inertia. Simulations were then carried out using the model under various system load conditions and using generation inertia only (ignoring governor actions) to calculate the resulting frequency from the initial 50 Hz value. The calculations are done using a spread sheet.

7.1.2 STUDY CASES

Four demand scenarios are used to assess the effectiveness of the proposed frequency standards. These scenarios include both high load and light load conditions in Tasmania with maximum import from Basslink and no Basslink import at all. The scenarios simulated are given in Table 7.2. The table shows Tasmanian system load, Basslink import and system inertia (based on 100 MVA) and System MVA.

Scenario	1	2	3	4
System Load inclusive losses(MW)	1090.1	1715.5	1605	1633
Basslink import	407.4	466.7	474.0	0.0
Inertia Constant (MWsec/MVA) on 100 MVA	49.8	71.9	92.0	101.2
System MVA (excluding wind farm)	1283	2029	2502	2703

Table 7.2 Simulated scenarios

In high Basslink flow level studies, the following contingencies were studied:

1. tripping of Basslink together with failure of FCSPS; and
2. high loss of generation (300 MW / 400 MW) due to any network event.

Loss of 400 MW generation will give a significantly higher rate of change of frequency and test the robustness of the setting selected.

Events more extreme than the above are reasonably possible, but are usually combined with the islanding of the Tasmanian system. These cases cannot be explored using this simplified model and will be considered in the more detailed modelling to be done later.

7.1.3 RESULTS

The results of studies are summarised in Table 7.3 and these are also shown graphically in figures 7.1 to figures 7.3

Scenario	**1**	**2**	**3**	**4**
Basslink Tripped (MW)	407.4	466.7	474	0
Initial df/dt(Hz/Sec)	-2.0452	-1.6227	-1.3605	
Load shed (MW)	388 / 5	478 / 4	459 / 4	
Frequency at 10 sec (Hz)	47.4	48.4	48.1	
Discrimination achieved with FCSPS / UFLSS?	Yes	yes	yes	
Generation lost (MW)	300	300	300	300
Initial df/dt(Hz/Sec)	-2.0661	-1.2557	-1.0528	-0.9030
Load shed (MW / No. of blocks)	308 / 3	263 / 2	259 / 2	257 / 2
Frequency at 10 sec (Hz)	47.9	48.4	48.2	48.2
Discrimination achieved with UFLSS?	yes	yes	yes	yes
Generation lost (MW)	400	400	400	400
Initial df/dt(Hz/Sec)	-3.1446	-1.7963	-1.5162	-1.2986
Load shed (MW / No. of blocks)	362 / 4	370 / 3	357 / 3	364
Frequency at 10 sec (Hz)	47.5	48.5	48.0	48.0
Discrimination achieved with UFLSS?	No	Yes	Yes	yes

Note: In case 4 generator tripping was modelled because it is assumed that frequency controller is off due to Basslink not in service.

Table 7.3 Summary of results

7.2 DISCUSSION OF RESULTS

The following sections briefly discuss the results and make summary observations from this high level analysis.

7.2.1 BASSLINK TRIPPING

The following observations are made from the high level studies involving Basslink tripping:

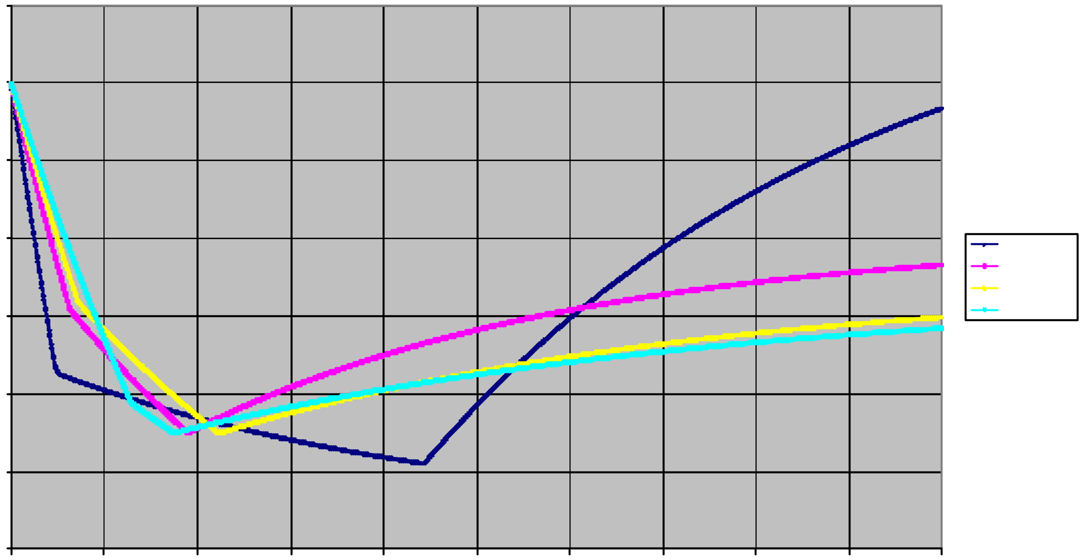
1. The results show for cases 1-3 involving a loss of Basslink tripping highest initial rate of change of frequency is less than 2.86 HZ / sec (the assumed design criteria for Basslink original FCSPS scheme) which ensures that discrimination is achieved between UFLSS and FCSPS scheme. Therefore FCSPS would assume to operate before UFLSS can operate.
2. In study 1 results show that frequency stays at 47.4 Hz indefinitely. It is to be noted that in the real system (to be simulated as part of detailed studies in next phase) the governor

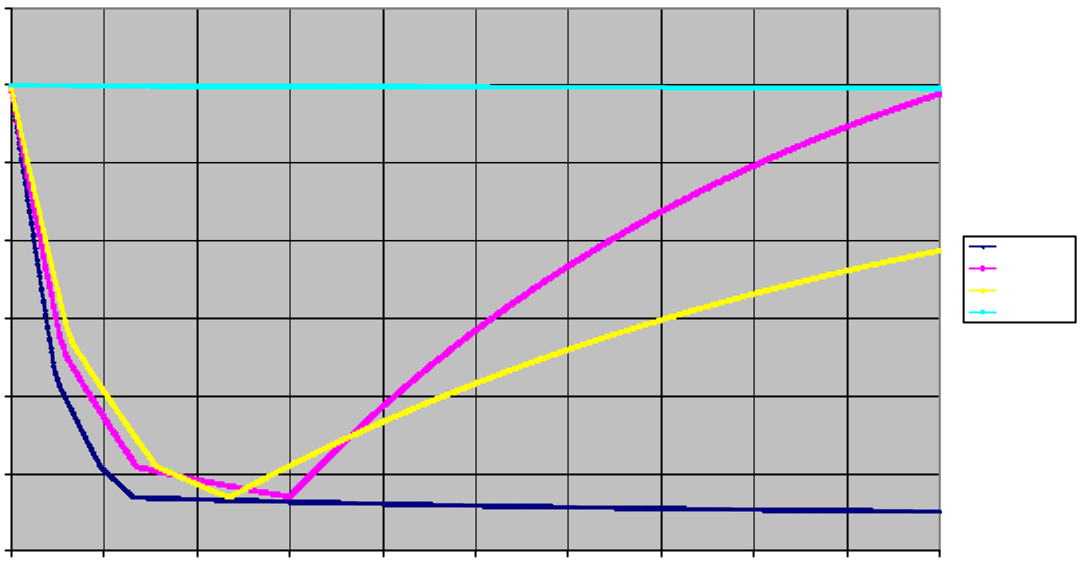
actions after inertia effect has died down will after some time restore the system frequency as FCAS service comes into effect.

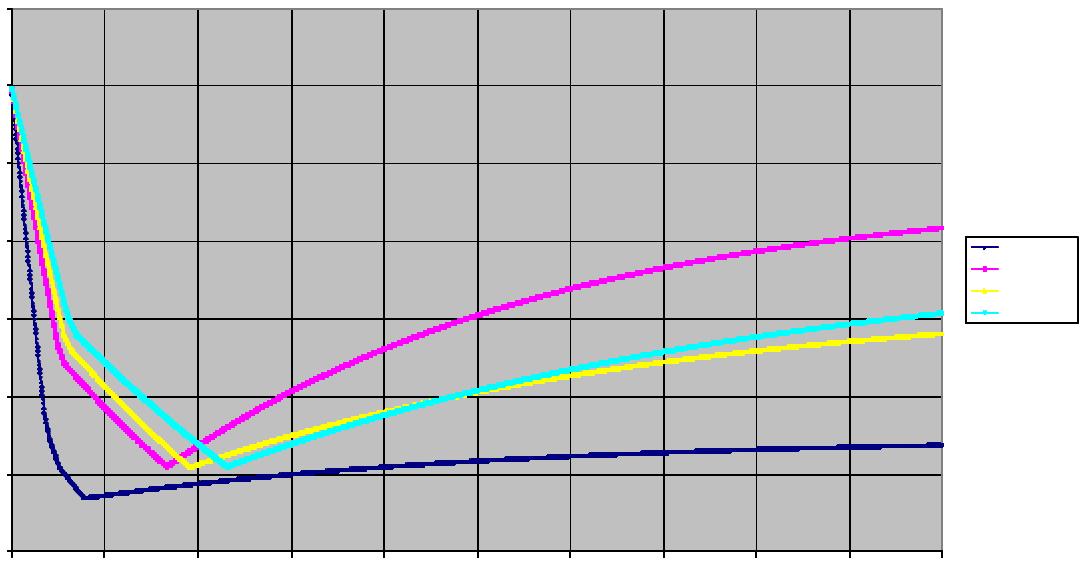
3. There could still be certain scenarios where frequency could stay between 47 Hz and 47.5 Hz longer than 20 seconds even after FCAS in the system has been taken into account. This is also the case with current UFLSS settings.
4. Frequency sustaining between 47 Hz and 47.5 Hz for more than 20 seconds would result in tripping of CCGT plants. In order to prevent tripping of CCGT plants, UFLSS scheme would have to have a secondary setting for blocks 4 to 7 with frequency setting higher than the primary setting but with a time delay of about 10 sec to ensure that frequency recovers above 47.5 Hz to prevent CCGT tripping.
5. The need for a Basslink FCSPS re-design will be required to be looked at in the detailed study stage to see whether it can meet the proposed frequency standards with adequate margins and that there is adequate discrimination with the re-designed UFLSS.

7.2.2 Generator Tripping

The results show that for loss of generation of 300 MW it is possible to achieve discrimination between the blocks of the proposed UFLSS, but not for loss of 400 MW of generation. For loss of 400 MW of generation block 2 picks up before block 1 sheds load because of very high df/dt. This really is not much of an issue as this block would trip in any case because of the large loss of generation. There would not be any unacceptable overshoot of frequency. As discussed in the previous section secondary frequency settings would be required for the reasons given before to ensure that the frequency recovered to acceptable levels in acceptable times. However as part of a more detailed study (next phase) this will be investigated in more detail.







It is therefore concluded from the high level studies that a **new UFLSS may be feasible to be designed to accommodate a frequency standard based around the characteristics of the Alinta plant.** However the new standard would require redesigning of the existing UFLSS in the following ways:

1. The frequency picks up points needs to be shifted up by 0.5 Hz.
2. The load steps need to be placed closer together in the frequency domain.
3. The load block size would remain the same as now but the loads will trip at a higher frequency.
4. A secondary delay time needs to be set for blocks 4 to 7 to ensure that after time out they trip loads to return the frequency to the regulation band under some unusual system conditions. ***(note: This is not a new requirement as under some situations this will be needed even now, when load generation balance are very close after loss of generation and some load shedding).***
5. The new UFLSS design needs to be tested with more extreme events than was possible in this study.
6. The Alinta Generator needs to be included in the OFGSS scheme and its setting should be properly coordinated with other generators in the OFGSS scheme. The re-designed OFGSS will need to be reviewed against compliance with the NER during the detailed modelling stage.
7. The existing FCSPS design may be required to be re-designed, particularly the generator tripping for loss of Basslink during export conditions and possibly the load shedding for loss of Basslink under import conditions. The discrimination between the new UFLSS settings and FCSPS operation will need to be reviewed, and there may be reserve management issues.

9. DETAILED STUDIES TO CONFIRM FREQUENCY STANDARD

The high level modelling studies assessed adequacy of the current operational arrangement to comply with the proposed frequency standard based on inertia models only. Further, the contingencies considered were limited to large loss of generation only to test the impact of severe events that will result in high rate of change of frequency resulting in fast decay of frequency from the steady state value of 50 Hz. The only response to arrest the frequency in such situations will come from the stored energy in the inertia of generation systems and some relief from the load that are frequency dependent, but the only way to arrest fequency is by load shedding. There is not enough time for governors to respond to increase mechanical power i.e. for FCAS to be effective. So in high level studies the effect of FCAS was ignored. The studies were therefore limited to only assessing whether the proposed changes to UFLSS scheme was adequate to comply with new frequency standard for multiple contingencies resulting in loss of large generation and tripping of Basslink with heavy import. Without detailed network models the separation event across some of the cutsets could not be modelled but may have significant impact on the frequency response and therefore on feasibility of developing a new frequency standard.. Also, without detailed representation of network and other control schemes the effect of co-ordination between different schemes in the system - FCSPS, UFLSS, OFGSS and over frequency / over speed protection on generators - to contain frequency within the band proposed in the proposed frequency standard could not be examined.

This section investigates studies with full system model representation of all controls to examine the findings from the high level model studies to confirm the new standard. The studies simulate all contingencies incorporating FCAS requirement and all other special protection schemes to contain frequency under all contingencies.

The purpose of the detailed studies is to identify changes that are required in despatching to the new frequency standard. These are:

- Amount of additional reserve requirement
- Additional load and generation to be armed in FCSPS
- Changes to UFLS settings
- Changes to OFGSS settings, and
- Any other changes based on studies

It is to be noted that the above list is not comprehensive. The issues as they arise from detailed studies will be documented and where appropriate high level solution proposed.

9.1 STUDY APPROACH

The focus for the detailed studies is to represent the Tasmanian system using detailed plant and control models using the power system analysis Software - PSS/E. The models and details are based on NEMMCO registered plant data used in NEM dispatch. Detail studies are conducted in the following two stages to assess.

Stage 1 - adequacy of current operating arrangement with reserve scheduled for largest generator contingency, which is loss of Gordon unit running at full capacity and if found inadequate identify changes to be made to enable compliance with the proposed frequency standard.

Stage 2 - Identify further changes to the arrangement with reserve scheduled for loss of a CCGT plant of 208 MW as the largest single unit connected to the system and any other issues in implementing the proposed standard

It should be noted the stage 1 findings will confirm the frequency standard robustness and therefore support changing frequency standard in Tasmania to accommodate gas turbine and thermal units. This is considered as a step towards moving the Tasmanian standard to the mainland standard. However on top of compressing the frequency standard to accommodate thermal units and CCGT technology generation, there is another key issue to be addressed in relation to the **maximum size of unit that is reasonably expected to be dispatched.** ***This issue will be covered in detail as part of the next phase of investigation following confirmation of the robustness of the proposed frequency standard. The main reason is that determining largest unit is a balance between the system size, reserve availability and the ability of the other control systems to be able to be designed to take timely control actions to prevent total system collapse. Such studies cannot be conducted till after a frequency standard to accommodate the CCGT is confirmed.*** However detailed simulations haves been carried out for loss of 208 MW of CCGT to identify the issues in stage 2 in this report as a precursor to investigate in the next part of the investigation.

The various key steps followed in detailed studies are shown in Figure 9.1 and are discussed in brief in the following sections.

Figure 9.1 Steps for Detailed Studies

9.2 INVESTIGATION SCENARIOS

In total six (6) dispatch scenarios as shown in Table 3-1 were identified as relevant for detailed modelling studies to confirm the high level simulation findings. These scenarios are considered as extreme but relevant test scenarios and cover a wide range generation dispatch patterns including significant transfer over Basslink. In setting up scenario study cases, possible islanding within Tasmanian region with very high imbalance between load and generation were selected. Such scenarios represent worst case scenarios with regard to testing robustness of the frequency standard against severe events in Tasmania. Thus if the performance of such cases demonstrate compliance to the frequency standard requirements of the NER, then it is considered as a viable standard. In all the scenarios Basslink transfer were set at limit: - ***export limit, import limit, blocked or no go zone*** to ensure that there is no FCAS service from mainland via Basslink. Compliance to such severe operating conditions should provide confidence with the viability of an appropriate frequency standard within the context of Tasmanian network and are therefore deemed as the worst case scenario.

Scenario 1	Summer peak, Low West coast, No wind farm, Basslink import
Scenario 2	Summer peak, Low West coast, wind farm running to full capacity, Basslink
Scenario 3	Summer peak, Medium gen. West coast(Pieman only), Basslink import
Scenario 4	Summer light, Basslink import
Scenario 5	Summer light, Basslink out
Scenario 6	Summer peak, Very high west coast, Basslink export

Table 9-1 Dispatch pattern for scenarios investigated

The cases for all these scenarios have been set up with <u>both thermal plants scheduled and operating at full capacity - Alinta's CCGT plant and GUNNS plant.</u> For those cases involving investigating present system conditions the schedule is adjusted by removing the CCGT and Gunns plant.

The scenarios selected are limited to summer conditions only because summer loads are lower compared to winter loads and therefore system has less inertia due to less generation plant dispatched to meet demand. Therefore, under such weak system conditions any loss of generation would have more severe impact on frequency compared to using winter condition when inertia would be higher because of higher load requiring more generation plants. It is to be noted Tasmanian system is a winter peak demand system. The light summer conditions is considered as further extreme condition and impose limit on Basslink import due to lower effective short circuit ration. Therefore investigating both light and peak load conditions during summer load conditions will provide sufficient confidence on the robustness of the standard, while identifying any issues that needs resolution. The outcome of such studies if proven to demonstrate adequate system performance within NER requirements, is considered as an acceptable standard, thus minimising risk of un-planned system collapse.

This section provides a brief description of the generation and demand balance make up. It should be noted that significant effort has been made to create unique but severe dispatch patterns to test the robustness of the frequency standard.

9.2.1 SCENARIO 1

SUMMER PEAK LOAD, LOW WEST COAST GENERATION, NO WIND FARM, BASSLINK IMPORTING MAXIMUM

This scenario is representative of dry hydrological conditions. In this scenario assumptions made on generation dispatch are:

- System demand : 1500 MW
- Basslink is importing maximum (500 MW at sending end)
- Very low generation in west coast
- No wind generation
- GUNNS and Tamar valley base load plant are running at full capacity
- Gordon is running low
- Stations on Great Lake and Derwent are running at medium load

As Basslink is importing maximum no FCAS raise service is available from it for any generator tripping. So, all FCAS would have to be provided within Tasmania.

9.2.2 SCENARIO 2

SUMMER PEAK LOAD, LOW WEST COAST GENERATION, FULL WIND FARM BASSLINK IMPORTING MAXIMUM

This scenario is similar to scenario 1, except that both Bluff point and Studland Bay wind farms are assumed to be in service and generating full under this scenario. The generation dispatch schedule in this case is adjusted by reducing MW without disconnecting any generators to maintain the same system inertia. The impact of disconnecting Gordon unit with consequent reduction in system inertia and rescheduling generation is also investigated to assess the impact of reduced inertia.

9.2.3 SCENARIO 3

SUMMER PEAK LOAD, MEDIUM WEST COAST, BASS LINK IMPORTING MAXIMUM 500 MW

This is also a summer peak load scenario with medium generation in west coast. Assumptions made on generation dispatch in this scenario are:

- System demand 1574 MW
- Basslink is importing maximum (500 MW at sending end)
- Medium generation in west coast
- No wind generation

- GUNNS and Tamar valley base load plant are running at full capacity
- Gordon is completely off
- Stations on Great Lake and Derwent are running at medium load

As Basslink is importing maximum **no** FCAS raise service is available from it for any generator tripping. So, all FCAS would have to be provided within Tasmania.

9.2.4 SCENARIO 4

SUMMER LIGHT, BASSLINK IMPORTING AT 50% LEVEL (250 MW)

This is a summer light load scenario with Basslink importing 250 MW. Assumptions made on generation dispatch in this scenario are:

- System demand:
- No generation in west coast
- No wind generation
- GUNNS and Tamar valley base load plant are running at full capacity
- Gordon one unit is partially loaded.
- Stations on Great Lake and Derwent are running at medium load

As Basslink is importing only 250 MW, significant amount of FCAS raise service is available from it.

9.2.5 SCENARIO 5

SUMMER LIGHT, BASSLINK OUT OF SERVICE

This is also a summer light load scenario similar to the previous scenario with Basslink out of service. As Basslink is out of service, dispatch schedule has been modified to balance load and generation. Assumptions made on the generation dispatch in this scenario are:

- Low generation in West coast (100 MW)
- Wind farm generating 95 MW
- GUNNS and Tamar valley base load plant are running at full capacity (208 MW + 213 MW)
- Low generation at Gordon (112 MW with two units on line)
- Stations on Great Lake and Derwent are running at medium load (74 MW + 218 MW)

John Butters and Reece Generators were switched in to provide adequate FCAS to maintain frequency for tripping of CCGT plant when fully loaded.

9.2.6 SCENARIO 6

SUMMER PEAK LOAD, HIGH WEST COAST, BASSLINK EXPORTING MAXIMUM (630 MW)

This is also a summer peak load case with very high generation in Tasmania and Basslink is exporting maximum (630 MW at sending end). Assumptions made on generation dispatch in this scenario are:

- System demand 1500 MW
- Very high generation in west coast
- No wind generation
- GUNNS and Tamar valley base load plant are running at full capacity
- Gordon running at 360 MW.
- Stations on Great Lake and Derwent are running at medium load

As Basslink is exporting maximum, **no** FCAS lower would be available from it. It is also implicit in this that adequate number of generators are armed to cover loss of major circuits.

9.3 MODELLING ASSUMPTIONS

9.3.1 NETWORK CONFIGURATION

The base network configuration used in this study is the network configurations as at Oct 2007 with the following changes to the network:

- Alinta's CCGT and OCGT and GUNNS power plant commissioned
- Studland Bay wind farm in operation with switched capacitor banks at Studland Bay 22 kV bus
- GUNNS power plant commissioned

In this configuration, the 110 kV split at Hampshire is retained and all the capacitor banks proposed in Transend 2007 Annual Planning Report are included. The network configuration also includes Basslink, and a simplified two-bus representation of the Victorian network.

In scenario 3, Lindisfarne-Waddamana 220 kV double circuit line is assumed to be in service.. This configuration is considered as appropriate in light of the proposed 220 kV line between Waddamana-Lindisfarne due for commissioning in 2010. Considering that this line will provide an alternative feed into Chapel street, it is considered essential to test the impact of the new line on system performance for a bus coupler fault on Chapel Street 220 kV bus.

9.3.2 PSS

In studies only PSS which are currently available are assumed.

9.3.3 FAULT TYPES AND FAULT CLEARING TIME

In studies faults considered are:

- Tripping of generators without fault
- Tripping of Basslink with FCSPS in operation. FCSPS is assumed to operate in 0.650 sec to shed load
- Tripping of Basslink with FCSPS failing to operate with consequential UFLSS operation
- Three phase bus coupler fault cleared in 0.1 sec. The clearing time includes CB opening time.

9.3.4 MODELLING

The models used in studies are discussed in this section:

Basslink

HVDC model CDCHT3 to represent Basslink. The model also includes frequency control (BFC), filter switching (BLQCT1), Under Voltage Control for DC Line (UVACLIM1), and transformer tap changer (DCTC1). In the model HVDC flow is limited to maximum of 500 MW during import conditions and 630 MW during export.

Wind Turbine Generators

As submitted by the market participants.

Thermal Plants

The models used to represent thermal machines are standard PSS/E models except for the following models which are user written models:

RRGOV1 – Governor Model for AL_OC#1 (Alinta's Open cycle gas plant)

MELCO - Exciter model for TVPS_GT and TVPS_ST (Alinta's combined cycle gas plant)

In studies the existing Bell Bay plants are assumed to be decommissioned following Alinta's commissioning.

It is assumed that gas turbine output does not reduce at lower frequency as no information is available on performance of turbine at lower frequencies.

Hydro Plants

The latest dynamic data file (Revision G) provided by Hydro Tasmania is used in studies which models all Hydro plants in the system.

Load Models

Models IEELOW and IEELAL are used to represent loads. These models represent load as a function of voltage and frequency as shown under:

Comalco 220 kV Load (280 MW)

$P = Pnominal\ V^{1.3} (1 – 0.3\ ?f)$

$Q = Q_{nominal}\ V^{2.5} (1 + 0.6\ ?f)$

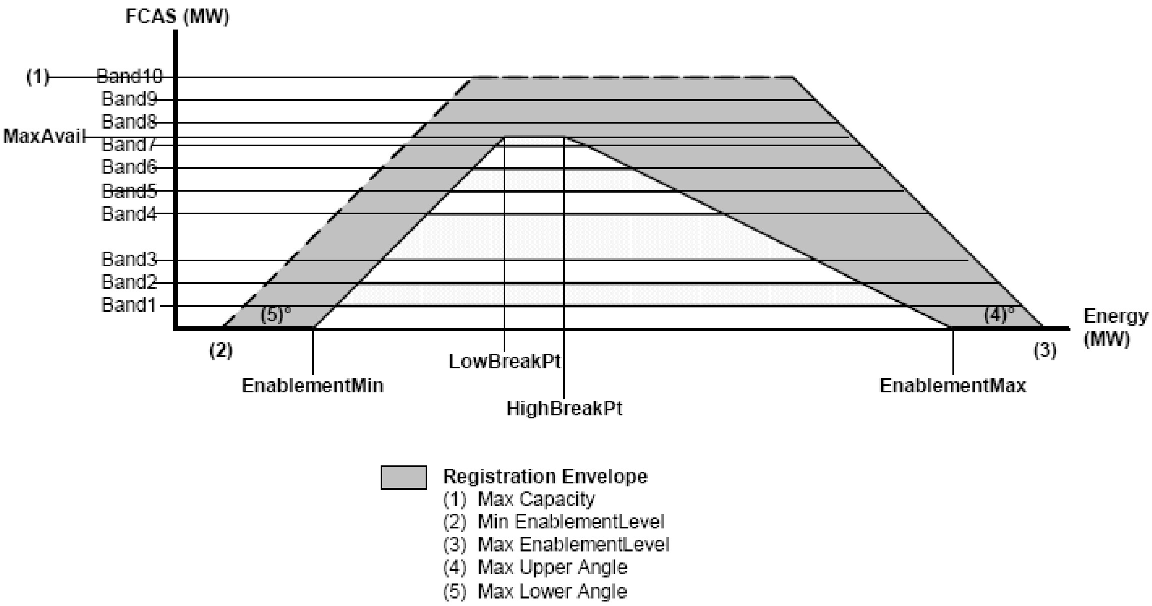
All other loads

$P = Pnominal\ V^{1.3} (1 + 1.0\ ?f)$

$Q = Q_{nominal}\ V^{2.5} (1 – 1.7\ ?f)$

FCAS

The technical envelope setting out FCAS capability of machines is defined as show in Figure 1.1. This figure is drawn from NEMMCO's registration guide[6].



FCAS available in each case is estimated using the technical envelope for hydro machines. For new thermal plants it is assumed that FCAS available is the difference between the maximum generation and scheduled generation. In the studies, as thermal generation is assumed to be running as base load station with maximum output, no FCAS raise would be available. However, FCAS lower would be available. ***Studies show that governors are able to lower generation very fast to low value in 2 seconds. We are not very sure whether machines are really capable of achieving this.***

[6] Generation Registration Guide, NEMMCO, http://www.nemmco.com.au/registration/110-0649.pdf

An IPLAN programme is used to estimate FCAS scheduled in study cases and if the available FCAS is found to be less than the FCAS required to mange generator contingency by less than around 20 MW, dispatch schedule is adjusted till adequate FCAS is scheduled. It is found from previous studies that actual FCAS available is more than the estimated FCAS; therefore a margin of 20 MW is used.

FCAS raise required to keep frequency above fmin Hz is estimated assuming no contribution from Basslink, using the equation:

FCAS raise = Generation loss – TAS load (excluding COMALCO load) * 1.0 * (50.0 –fmin) / 50 + COMALCO load * 0.3 * (50.0 –fmin) / 50 where, 0.04 pu/pu is the maximum frequency deviation allowed for generator contingency

1.0 pu is the load relief factor for all loads other than COMALCO load

0.3 Load relief factor due to frequency

If Basslink is importing maximum (500 MW at sending end), no FCAS raise would be available.

In estimating FCAS raise required, load relief due to reduction in voltage is ignored.

Contingency of Gordon plant generating (144 MW) = 87.6 MW

Contingency of Alinta CCGT plant generating (208 MW) = 151.6 MW

So, for outage of CCGT plant FCAS required would be 64 MW (208 – 144) more than what would be required for outage of the largest existing plant now.

Actual FCAS available could be more than the estimated value due to inertial considerations (rapid rates of frequency change which increase FCAS requirements above the linear approximation).

Under frequency relay model

Under frequency relay model is a user written model which represents the relay used in the system. The relay models four stages with two elements to measure:

1. average rate of change of frequency (Df/Dt) over a set period after the trigger frequencies is reached and initiate load shedding when rate of change of $\Delta f/\Delta t$ is lower than the set value. Please note that $\Delta f/\Delta t$ is negative for an under frequency event.
2. to measure frequency and initiate load shedding when the trigger frequency is reached after a set time delay has lapsed.

Over-frequency relay model

Over frequency relay used is similar to the relay used in UFLSS. Over frequency relay model is also a user written model which represents the relay used in the system.

FCSPS

In order to simulate FCSPS operation for Basslink tripping, loads / generators to be dropped are identified by using an IPLAN program, and in stability studies these loads / generators are dropped 0.65 sec after Basslink is tripped. The tripping of Basslink is simulated by blocking it.

Network

The impedance of network elements is made frequency dependent to allow for the changes in impedance associated with large changes in system frequency.

9.4 PROPOSED FREQUENCY STANDARD PERFORMANCE CRITERIA

The simulation studies are intended to assess if the proposed frequency standard could be met within the NER. The NER expectation is the Frequency performance of the system under contingencies within rules must ensure there is no breach of the standard. It is therefore expected that the study results should meet the following proposed frequency standard requirements:

- Minimum system frequency **for generator contingency should not fall below 48 Hz.** It should preferably be above 48.2 Hz to allow a margin for model inaccuracies and error in estimating FCAS
- Minimum system frequency **for Basslink tripping** when importing with FCSPS operating **should not fall below 48 Hz.**
- Minimum system **frequency for Basslink tripping when importing with FCSPS failing** to operate **should be limited to 47 Hz by UFLSS**.
- **Maximum frequency for Basslink tripping** when exporting with FCSPS operating should **not rise higher than 52 Hz in islands where thermal plants are connected**
- **Islands that are formed with only hydro generators**, frequency could **go up to 55 Hz**
- For any **network contingency** resulting in loss of generation minimum frequency should be **limited to 47 Hz** by UFLSS and it should not also **stay below 47.5 Hz for more than 10sec**

Table 9-2 Proposed frequency Standard

Condition	Containment	Stabilisation	Recovery
Interconnected Operation			
No contingency or load event	49.75 to 50.25 Hz, 49.85 to 50.15 Hz 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Load event	49.0 to 51.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Generation event	48.0 to 51.0 Hz (47.5 to 51.0 Hz)	49.85 to 50.15 Hz within 5 minutes	
Network event	48.0 to 52.0 Hz (47.5 to 53.0 Hz)	49.0 to 51.0 Hz within 1 min	49.85 to 50.15 Hz within 5 min
Separation event	47.0 to 55.0 Hz (46.0 to 55.0 Hz) With thermal units allowed to trip at 52 Hz	48.0 to 51.0 Hz within 2 min (47.0 to 51.0) Hz	49.85 to 50.15 Hz within 10 min
Multiple contingency event	47.0 to 55.0 Hz (46.0 to 55.0 Hz) With thermal units allowed to trip at 52 Hz	48.0 Hz to 51.0 Hz within 2 min	49.85 to 50.15 Hz within 10 min
Islanded Operation			
No contingency or load event	49.0 51.0 Hz		
Load event	49.0 to 51.0 Hz	49.0 to 51.0 Hz within 10 min	
Generation event	48.0 to 51.0 Hz (47.5 to 51.0 Hz)	49.0 to 51.0 Hz within 5 min	
Network event	48.0 to 52.0 Hz (47.5 to 53.0 Hz)	49.0 to 51.0 Hz within 1 min	49.85 to 50.15 Hz within 5 min
Separation event	47.0 to 55.0 Hz (46.0 to 60.0 Hz) With thermal units allowed to trip at 52 Hz	48.0 Hz to 51.0 Hz within 2 min	49.85 to 50.15 Hz within 10 min
Multiple contingency event	47.0 to 55 Hz (46.0 to 55.0 Hz)	48.0 Hz to 51.0 Hz within	49.85 to 50.15 Hz within

	With thermal units allowed to trip at 52 Hz	2 min	10 min

		48.0 to 51.0 Hz	**48.0** to 51.0 Hz
		48.0 to **52.0** Hz	**48.0** to **52.0** Hz
		47.0 to **55.0** Hz With thermal units allowed to trip at 52 Hz	**47.0** to **55.0** Hz With thermal units allowed to trip at 52 Hz

plant

2. Tripping of Alinta's CCGT plant
3. Basslink tripping with failure of FCSPS
4. Basslink tripping and operation of FCSPS
5. 220 kV bus coupler fault at Sheffield 220 kV with110 kV network split at Hampshire.
6. 220 kV bus coupler fault at Palmerston 220 kV with Palmerston–Hadspen 110 kV circuits out of service (oos)
7. 220 kV bus coupler fault at Chapel Street 220 kV with Waddamana–Palmerston 110 kV circuit out of service

It is to be noted:

– Bus coupler fault at Sheffield splits the system to three islands: 1 – West coast, 2 – North west coast and 3 – remaining part of the system with Basslink. In addition some generators also would get disconnected from the system

– Bus coupler fault at Palmerston with Palmerston-Hadspen 110 kV circuits out splits the system into two islands: 1 – region north of Palmerston and 2 – region south of Palmerston.

In addition Poatina generators connected to Palmerston 220 kV bus would get disconnected from the system

– Bus coupler fault at Chapel Street with Waddamana-Palmerston 110 circuit out splits the system into two islands: 1 – region north of Liapootah with Derwent 220 kV generation connected and 2 – region south of Liapootah with only Derwent 110 kV generation as Gordon generation gets disconnected. In scenario 3, no islanding occurs , because the network configuration assumes that Lindisfarne-Waddamana 220 kV configuration is complete.

10. SIMULATION RESULTS AND DISCUSSIONS

This section presents results of simulations carried out and discusses the results. The results are presented graphically and the plotted results show frequency, Tasmanian system mechanical power and load shedding, if relevant for all scenarios. The Tasmanian total mechanical power is the sum of all generator mechanical input power and it is intended to show how FCAS service responds under contingencies.

10.1 BROAD CATEGORY OF STUDIES

Two sets of studies are performed to assess compliance with the proposed frequency standard. These are:

A. **Present largest unit size:** Studies with FCAS raise set to cover contingency of Gordon unit running at full capacity (144 MW). This is present situation and is used as reference for assessing increased reserve requirement for the proposed standard. In these studies both CCGT and GUNNS plants are not in service. So Gordon unit is the largest unit in service.

B. **Future largest unit size:** Studies with FCAS raise set to cover contingency of a future scenario of loss of CCGT or GUNNS generator running at full capacity of 208 or 213 MW respectively.

The studies also determine additional load required to be armed under FCSPS to cover contingency of Basslink. It should be noted that reserve required to comply with new frequency standard is higher. For example at system load of 1500 MW additional reserve required will increase by 15 MW. The increase is essentially required to compensate for load relief lost for the ½ Hz shift up required to accommodate CCGT characteristics for a generator contingent event band.

The studies in 'A' above as mentioned earlier are essentially intended to demonstrate that the proposed frequency standard will not significantly alter existing operating arrangement by compressing the frequency operating band to accommodate the CCGT type of characteristics in Tasmania. It is essential that detailed studies demonstrate that this is achievable thus providing path way to establishing a new standard and thus allowing new generators with CCGT and thermal characteristics to be able to be connected to the grid in compliance with the NER. This is a critical issue as with this change it will remove access difficulties currently exists for CCGT type of plants to be able to be registered for operation in Tasmania.

The second issue is of importance in determining the permissible largest unit size for the Tasmanian system. The Case B investigates the issue of adequacy of market dispatched reserve availability in Tasmania to allow unconstrained dispatch of CCGT plant under all demand and generation scenarios to stay within the frequency envelope of CCGT. The issue is complex in that it is a trade off between the cost of procuring the reserve if it is available with the cost of constraining the plant. There are many alternative mechanisms for addressing the reserve issues resulting from the increased size of the unit. This has already been scoped out as the next phase of investigation in detail. However in this report the studies have been conducted to assess the issues associated with reserve requirements for the CCGT unit size being considered by Alinta. This wills set scene for further work to be done in the next phase.

10.2 DESIGN MARGIN

As part of the original design studies for Basslink connection (including FCSPS design studies) to the Tasmanian system, a number of simulation studies were conducted prior to approval of the connection. These studies used the detailed models that were prevailing at that time. As there were no prior operational experience with an interconnected system to the mainland a design margin of 0.5 Hz was used in the final design of FCSPS scheme to allow for modelling errors. However since Basslink was commissioned in 2005, there is 2 and ½ years of operating experience data available. Some of the system incidence traces to date has been bench marked against the modelled output using the same data to validate accuracy of models. A limited sample shows that there is a reasonably good correlation between the actual frequency trace from a system incident to those that are derived from the simulation indicating there is room for relaxing the safety margin. However there is insufficient sample sets to statistically establish the degree of confidence. Therefore it is unlikely that the entire design margin will be eliminated. It is considered that the original 0.5 HZ could be possibly relaxed down. It is not clear by how much it could be relaxed. In our studies no design margin has been considered as these studies are not intended for redesigning FCSPS at this stage.

10.3 DISCUSSION OF STUDY SCENARIOS

The study results for both categories of unit size: present size and future size are discussed under the following events:

– Generator event

– Basslink event
– Multiple contingency event

The intention is to assess compliance to the NER requirements for the proposed standard across all scenarios and cases. The results are presented for all six scenarios discussed in earlier sections. For ease of reading these are presented below:

1. Summer peak, Low West coast, No wind farm, Basslink importing to full capacity
2. Summer peak, Low West coast, wind farm running to full capacity, Basslink importing full capacity
3. Summer peak, Medium gen. West coast(Pieman only), Basslink importing to full capacity
4. Summer light, Basslink importing 50% of capacity
5. Summer light, no wind farm, Basslink out of service
6. Summer peak, very high west coast, Basslink exporting full capacity

10.4 GENERATOR EVENT (48.0 TO 51.0 HZ COMPLIANCE BAND)

The generator event compliance study is carried out for all six scenarios discussed in earlier section. The generator events considered are: *contingency of Gordon, Alinta's CCGT and GUNNS*. The purpose of these studies is to assess whether frequency stays within the compliance band. The results for all scenarios are shown graphically and discussed

10.4.1 FCAS RAISE SET TO COVER CONTINGENCY OF GORDON UNIT

In these studies CCGT and GUNNS are not connected and at least one of Gordon units is scheduled at full capacity (144 MW). Figure 10.4.1 shows frequency and Tasmanian system mechanical power for tripping of Gordon unit.

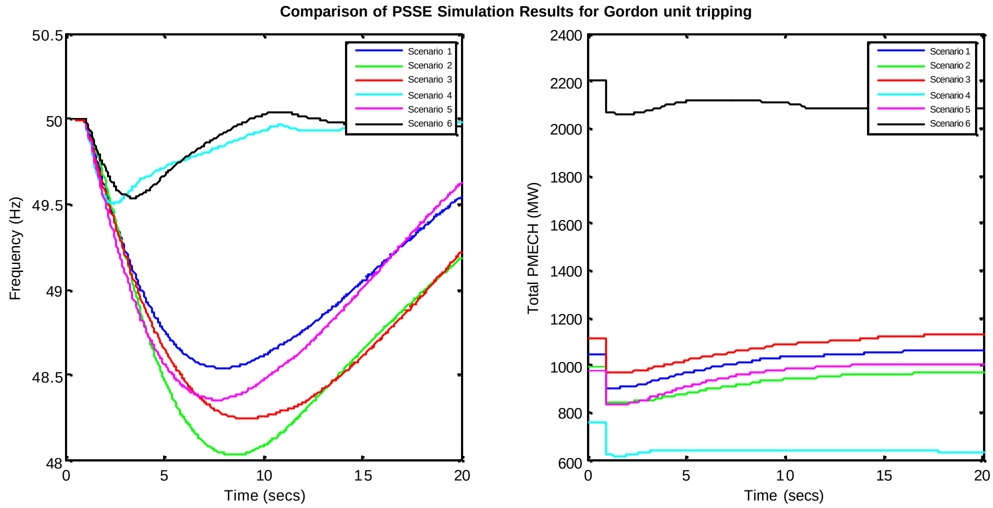


Figure 10.4.1 Frequency and TAS Pmech for Gordon unit trip

The following observations can be made from the graph:

a. Minimum frequency is above 48 HZ indicating that FCAS estimated is adequate.

b. In scenarios 1, 3, 5 FCAS could be reduced further to increase frequency drop to 48.0 Hz. This would result in increase in additional load to be armed for FCSPS tripping.

c. In scenario 4 because Basslink is importing only 50% of its capacity, there is sufficient FCAS raise available from Basslink. Therefore frequency does not drop down much.

d. In scenario 6 as Basslink is exporting, Basslink frequency controller can pull back export very quickly, i.e. very high FCAS raise, therefore frequency does not drop down much

10.4.2 FCAS RAISE SET TO COVER CONTINGENCY OF CCGT UNIT

In these studies CCGT and GUNNS are assumed to be in service and are scheduled at full capacity (208 / 213 MW). The generator contingencies considered are: *tripping of CCGT unit and tripping of GUNNS* thus increasing the unit size by 64-69 MW from the present largest size of 144 MW.

10.4.2.1 CCGT Tripping

Figure 10.4.2 shows frequency and Tasmanian system mechanical power for tripping of CCGT

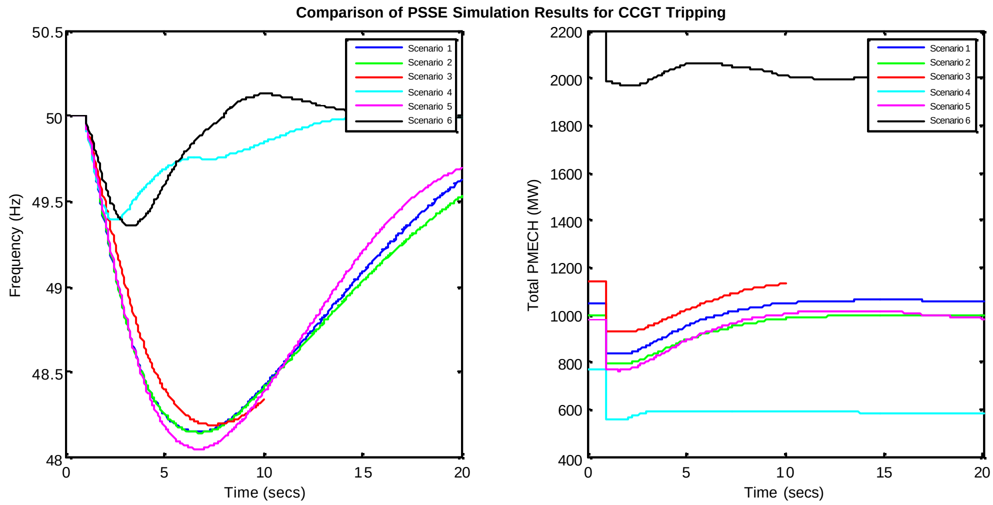


Figure 10.4.2 Frequency and TAS Pmech for CCGT trip

The following observations can be made from the graphs

a. Minimum frequency is above 48 Hz and below 52 Hz in all scenarios

b. In case of scenarios 1, 3, 5 FCAS could be reduced further to increase frequency drop to 48 Hz. This would increase additional load to be armed under FCSPS to cover Basslink tripping.

c. In case of 4 because Basslink is importing only 50% of its capacity, ample FRAISE is available. Therefore frequency does not go down much.

d. In case of scenario 6 as Basslink exporting Basslink frequency controller can pullback export very quickly, i.e. very high FCAS, frequency drop is not much

10.4.2.2 GUNNS tripping

Figure 10.4. 1 shows frequency and Tasmanian system mechanical power for tripping of CCGT

It can be seen from the graphs that frequency stays above 48 Hz and Below 52 Hz in all scenarios

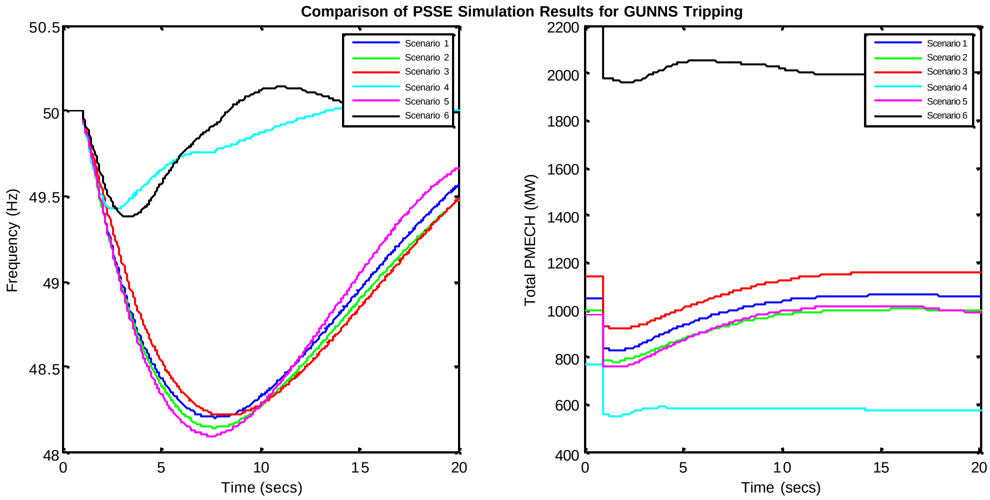


Figure 10.4.1 Frequency and Pmech for GUNNS trip

10.5 BASSLINK EVENT

Two Basslink events are investigated to assess compliance to following events:

- Tripping of Basslink with FCSPS operating correctly
- Tripping of Basslink with FCSPS failing to operate resulting in backup UFLSS shedding load to mange system frequency

Both these events are studied with FCAS set at a level as discussed in section 10.4.1. The studies also determine additional load if any required to be armed under FCSPS to cover contingency of Basslink.

An IPLAN programme is used to estimate the amount of load to be armed in the current FCSPSfor shedding when Basslink trips while importing to maintain frequency above 47.5 Hz. The amount of load to be armed is a function of total system load. Initial studies showed that Δf/Δt relay of UFLSS scheme operated and shed 1st block of load even after FCSPS had shed load. The lack of discrimination between UFLSS and FCSPS was due to average Δf/Δt over measurement period being higher than the set point. In studies therefore to achieve discrimination Δf/Δt setting is increased to 1.2 Hz/sec. Δf/Δt relay is not really providing much benefit because of long measurement period.

10.5.1 BASSLINK TRIPPING WITH FCSPS OPERATING

FCAS raise set to cover contingency of Gordon

Simulation studies were carried out with FCAS set to cover loss of Gordon unit as largest contingency. It is found that with all FCSPS armed load shed, frequency drops to below 48 Hz in 3 scenarios involving Basslink at full import.. However when Basslink import is at 50%, the frequency turned around to be above 48 Hz. In the remaining two cases frequency dropped below 47.5 Hz.

Further studies were carried out for these cases to determine additional load that need to be armed to comply with frequency standards, for both current and the proposed.

Figure 10.5.1 Frequency and Pmech for Basslink trip with FCSPS (FCAS for GO trip) shows plot of system frequency and Tasmanian system mechanical power on the basis that sufficient amount of load is armed as part of FCSPS scheme to comply with the current and proposed frequency standard.

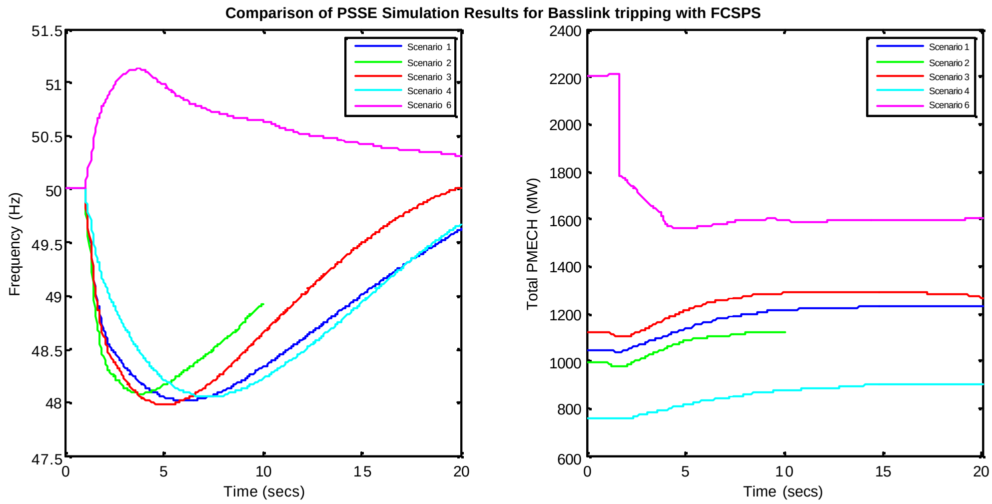


Figure 10.5.1 Frequency and Pmech for Basslink trip with FCSPS (FCAS for GO trip)

Further the Table 10.1 presents frequency that would be reached with load shed equal to load calculated by IPLAN programme for arming in FCSPS, when importing. The table also shows additional load that is required to be armed in the FCSPS scheme to be armed to pull frequency to 47.5 Hz and 48 Hz respectively. An alternative to the load shedding is to provide increased FCAS from generators. The amount of FCAS required would depend upon how fast minimum frequency is reached.

Table 10.1 FCSPS Load shedding Table

Scenario	**1**	**2**	**3**	**4**
Description				
Minimum Frequency reached (Hz) with UFLSS blocked	47.6	44.0[a]	42	48.06
Load shed by FCSPS (MW)	338	338	338	164
Additional load to be armed in FCSPS to limit to 48 Hz	30	85.3[b]	87[d]	Nil
Additional load to be armed in FCSPS limit to 47.5 Hz	Nil	66.7[c]	58[e]	Nil[f]
Extra load due to shifting frequency band by 0.5 Hz	**30**	**28,6**	**29**	**Nil**

Notes
a. Both Studland Bay (at 3.34 sec, @ 46.96 Hz) and BF (at 5.56 sec @ 46.34 Hz approx.
b. Actual frequency is 48.06 Hz
c. Actual frequency reached is 47.6. So, load could be reduced slightly
d. If FCAS is increased from64.8 MW to 100.4 MW load to be shed could be reduced to 59 MW
e. If FCAS is increased from64.8 MW to 100.4 MW load to be shed could be reduced to 14 MW
f. FCAS could be reduced slightly.
Scenario 5 is not included in the table as Basslink is out of service and Scenario 6 is not included as Basslink is exporting

When Basslink is tripped while exporting, frequency rises to 51.1 HZ, which is within the frequency band allowed.

10.5.2 FCAS raise set to cover contingency of CCGT

The simulations were conducted for loss of CCGT as largest contingency. The results with FCSPS armed shed load correctly, the frequency is found to go below 48 Hz in only scenario 2. Further studies were then carried out to determine the additional load that need to be armed to comply with the proposed frequency standard..

Figure 10.5.2 shows frequency and Tasmanian system mechanical power with enough load armed to comply with the current and proposed frequency standard.

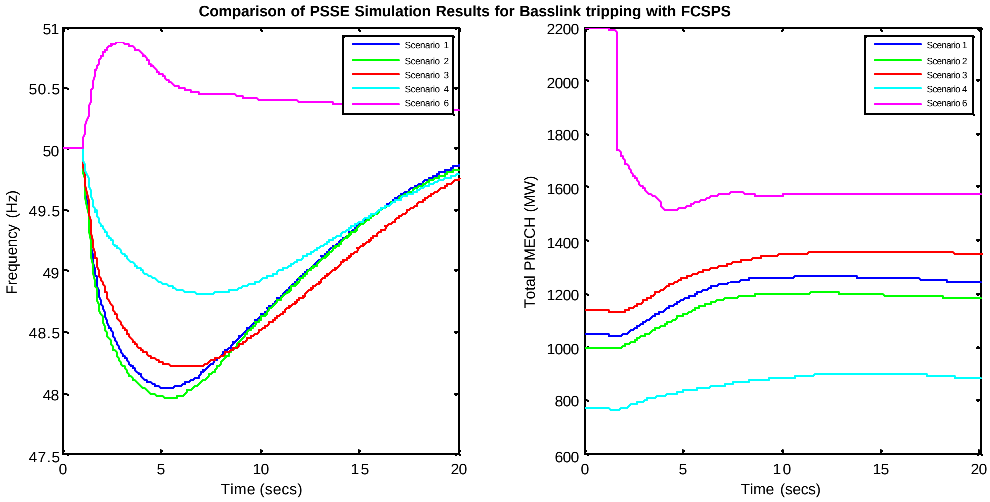


Figure 10.5.2 Frequency and Pmech for Basslink trip with FCSPS (FCAS for CCGT trip)

Figure10.2 shows frequency that would be reached when importing with load shed equal to load calculated by IPLAN programme for arming in FCSPS. The table also shows additional load to be armed to pull to pull frequency up to 48 Hz. The frequency could also be pulled up by increasing FCAS.

Table 10.2 System performance for Basslink tripping with FCSPS (FCAS for GO trip)

Scenario	**1**	**2**	**3**	**4**
Description				
Minimum Frequency reached (Hz) with UFLSS blocked	48.04[a]	47.83	48.2[b]	48.8[c]
Load shed by FCSPS (MW)	338	338	338	164
Additional load to be shed to limit to 48 Hz	**Nil**	**15**	**Nil**	**Nil**

Notes

a. The amount of load to be armed for tripping calculated by IPLAN programme displays a warning message: Not enough loads available for tripping. Load armed 338 MW

b. FCAS could be reduced slightly to increase frequency drop to 48 Hz

c. FCAS could be reduced significantly to increase frequency drop to 48 Hz

Basslink exporting

When Basslink is tripped while exporting, frequency rises to 52.13 HZ. The generators armed for tripping in FCSPS are Gordon 2,3 , Reece 1, Cethana. If FCSPS is modified to include more generation in the list to comply with new frequency standard, frequency could be contained below 52 Hz. However, it is to be noted that the current FCSPS generation arming is designed to limit frequency to 53 Hz with a design margin of 0.5 Hz. Therefore relaxing design margin and adding more generators to the tripping list will have to be considered to contain frequency within the proposed frequency standard requirement.

10.5.2.1 BASSLINK TRIPPING WITH FAILED FCSPS OPERATION

These studies assess the impact on a Basslink contingency with FCSPS failing to operate, with FCAS set to cover contingency of Gordon / CCGT to comply with the proposed standard. The studies also determine addition load if any required to be armed under FCSPS to cover the Basslink contingency.

Basslink tripping with FCSPS failing to operate is treated as a multiple contingency event. It is to be noted that the frequency band for compliance for such an event is 47 – 55 Hz if no thermal units are connected to the system and 47 – 52 Hz if thermal units are connected to the system

10.5.2.1.1 FCAS raise set to cover contingency of Gordon

Simulations were carried out for loss of Basslink on the basis the FCAS is set to cover loss of Gordon unit. Figure 10.5.2.1 shows frequency and load remaining in the system after blocks of load are shed. Load shed is relevant only in scenarios 1 to 4 where Basslink is importing. It can be seen from Figure 10.5.2.1 that frequency is maintained above 47 Hz by UFLSS when Basslink is importing and frequency is limited below 53 Hz by OFGSS. It should be noted that as there is no thermal units connected to the system under this study scenario, therefore the proposed standard allows frequency to reach up to 55 Hz.

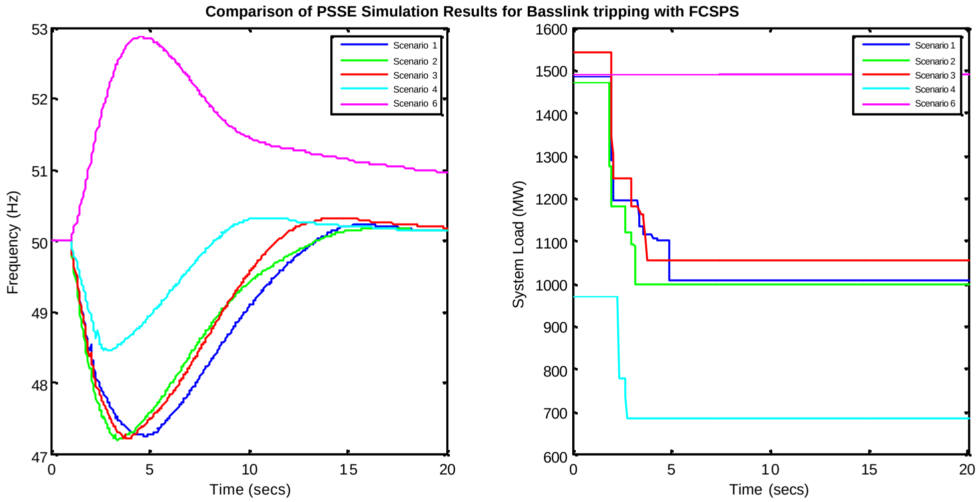


Figure 10.5.2.1 Frequency and Pmech for Basslink trip without FCSPS (FCAS for GO trip)

10.5.2.2 FCAS set to cover contingency of CCGT.

Studies in previous section were repeated with FCAS set to cover loss of CCGT. Figure 10.5.2.2 . Figure 10.5.2.2 shows frequency and load remaining in the system after blocks of load are shed. Load shed is relevant only in scenarios 1 to 4 where Basslink is importing. It can be seen from the figure that frequency is maintained above 47 Hz by UFLSS when Basslink is importing and frequency is limited below 55 Hz by OFGSS. It should be noted that as both thermal units are connected to the system, over-frequency has to be limited. The **maximum frequency reached is 52.13 Hz**. This is due to thermal units (Alinta's CCGT and GUNNS) not being included in OFGSS scheme. If these two plants are included in the scheme, frequency could be limited below 52 Hz. However, If these units are not included in OFGSS, these units will trip and cause under frequency load shedding. However their inclusion on OFGSS could itself need to be investigated as coordination may be an issue depending on whether there is any thermal plant capability above 52 Hz. In any case it is very unlikely the frequency will stay above 48 Hz because loss of 400 MW is a significant generation loss would likely to cause the frequency to go below 48 HZ requiring under frequency load shedding. Since this is a separation event the NER rule may permit it but this needs to be further examined.

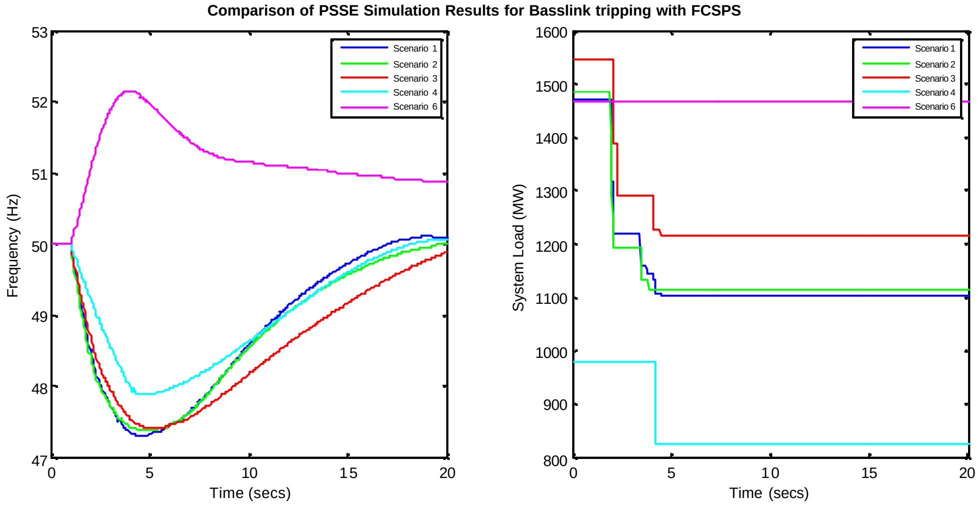


Figure 10.5.2.2 Frequency and Pmech for Basslink trip with FCSPS (FCAS for CCGT trip)

10.6 MULTIPLE CONTINGENCY EVENT

Multiple contingency events considered are bus couple failure events which results in Tasmanian system islanding. The bus couple faults studied are:

- Sheffield bus coupler fault
- Palmerston bus coupler fault
- Chapel street bus coupler fault

In case of Palmerston Bus coupler fault study, both Palmerston-Hadspen circuits are taken out to create islanding scenario. Similarly in case of Chapel Street bus coupler fault study, Palmerston-Waddamana 110 kV circuit is taken out.

The results are presented in tabular form. The table shows maximum and minimum frequency. Maximum frequency is for the island with excess generation and minimum frequency is for islands with deficit of generation. The table also, in the comments indicates non-viability of any islands. Viability of island depends on whether any generation is available in the island and whether load-generation balance could be achieved even after load shedding; This condition is scenario dependent. If no generators are scheduled in an island, this island would also suffer black out; So, this condition is scenario dependent.

In studies loads and generation shed for under / over frequency in islands.

10.6.1 Sheffield Bus coupler fault

For a Sheffield bus coupler 3 islands are formed:

1. north-west coast region;
2. west coast region; and
3. remaining region.

Viability of island of island 1 depends upon whether there are synchronous generators and whether load-generation balance could be achieved. In the cases considered here because Devils Gate and Paloona are not scheduled, this island is not a viable therefore this island would suffer black out even with Wind farm in service. The wind farm cannot run in islanded mode without reactive support in the island. This is not an issue with CCGT connection because this is true even now. Therefore, performance of this island is not discussed.

10.6.1.1 FCAS set to cover contingency of Gordon

Table 10.3 shows maximum and minimum frequency for Sheffield bus coupler fault. It can be seen from the figure that system frequency in viable islands is within limits

Table 10.3 System Frequency for Sheffield Bus coupler fault (FCAS for GO)

Scenario	Maximum Frequency Hz	Minimum Frequency Hz	Comments
1	50.55	48.06	Island 1 Not viable
2	53.68	45.38 49.73	Island 2 Island 1
3		49.13	Island 1 not viable
4	50.23		Island 1 & 2not viable
5		48.46	Island 1 & 2not viable
6		48.43	Not viable
Note: 3 islands formed: 1 – North West Coast; 2 – West Coast 3 – remaining part of the system			

10.6.1.2 FCAS set to cover contingency of CCGT

Table 10.4 shows maximum and minimum frequency for Sheffield bus coupler fault. It can be seen from the figure that system frequency in viable islands is within limits

Table 10.4 System Frequency for Sheffield Bus coupler fault (FCAS for CCGT)

Scenario	Maximum Frequency Hz	Minimum Frequency Hz	Comments
1	50.4		island 1 not viable
2	50.3	47.7	island 1 not viable
3		48.8	islands 1 & 2not viable
4	50.4		
5	51.35	49.76	island 1not viable
6		48.52	islands 1 & 2 not viable
Note: 3 islands formed: 1 – North West Coast; 2 – West Coast 3 – remaining part of the system			

10.6.2 PALMERSTON BUS COUPLER FAULT

For a Palmerston bus coupler 3 islands are formed:

1. North of Palmerston
2. South of Palmerston

10.6.2.1 FCAS set to cover contingency of Gordon

Table 10.5 shows maximum and minimum frequency for Palmerston bus coupler fault. It can be seen from the figure that system frequency in viable islands is within limits for all scenarios except for export scenario (6) and light load scenario (5) Maximum frequency reached is 53.4 Hz. This could be limited to 52 Hz by redesigning OFGSS and if the CCGT and Gunns generators are able to stay in service above 52 Hz for a few seconds to achieve co-ordination.

Table 10.5 System Frequency for Palmerston Bus coupler fault (FCAS for GO)

Scenario	Maximum Frequency Hz	Minimum Frequency Hz	Comments
1	50.52	48.48	
2	50.73	48.34	
3	50.73	49.49	
4	51.65	48.02	
5	53.02	48.02	
6	53.98	48.34	
Note: 2 islands formed. 1-North of Palmerston. 2 – South of Palmerston			

10.6.2.2 FCAS set to cover contingency of CCGT

Table 10.6 shows maximum and minimum frequency for Palmerston bus coupler fault. It can be seen from the figure that the system frequency in viable islands is within limits for all scenarios except for export scenario in the island north pf Palmerston. Maximum frequency reached is 53.4 Hz. This could be limited to 52 Hz by redesigning OFGSS and if generators are able to stay above 52 Hz for a few seconds to achieve co-ordination.

Table 10.6 System Frequency for Palmerston Bus coupler fault (FCAS for CCGT)

Scenario	Maximum Frequency Hz	Minimum Frequency Hz	Comments
1	50.5	48.1	
2	50.8	47.7	
3	50.7		island 2 not viable
4	50.7	48.7	
5	50.4	49.8	
6	53.4	50.4	
Note: 2 islands formed. 1-North of Palmerston. 2 – South of Palmerston			

10.6.3 CHAPEL STREET BUS COUPLER FAULT

For a Chapel Street fault 2 islands are formed in scenarios 1, 2, 4, 5 and 6:

1. North of Liapootah with Derwent 220 kV generation
2. South of Liapootah

In case of scenario 3 no islands formed because Lindisfarne-Waddamana 220 kV line is assumed to be commissioned.

10.6.3.1 FCAS set to cover contingency of Gordon

Table 10.7 shows maximum and minimum frequency for Chapel Street bus coupler fault. It can be seen from the figure that system frequency in viable islands is within limits for all scenarios except for scenario 4 to 6 where minimum frequency is below the proposed standard. Minimum frequency reached in scenario 4 and 5 is 46.9 and in scenario 6 it is 43.8. In order to increase frequency to above 47 Hz, load shedding in the island would have to be increased. The problem would not exist when Lindisfarne-Waddamana line is completed as southern part of the system would not be islanded.

Table 10.7 System Frequency for Chapel Street Bus coupler fault (FCAS for GO)

Scenario	Maximum Frequency Hz	Minimum Frequency Hz	Comments
1	50.5		Island 2 not viable
2	50.7		Island 2 not viable
3		47.53	
4	50.14	46.87	
5	52.37	47.09	Island 2
6		49.5 43.8	Island 1 Island 2
Note: 2 islands formed. 1 – North of LI with Derwent 220 kV gen; 2 - South of LI			

10.6.3.2 FCAS set to cover contingency of CCGT

Table 10.8 shows maximum and minimum frequency for Chapel Street bus coupler fault. It can be seen from the figure that system frequency in viable islands is within limits for all scenarios except for scenario 4 to 6 where minimum frequency is below the proposed standard. Minimum frequency reached in scenario 4 and 5 is 46.9 and in scenario 6 it is 44.74. In order to increase frequency to above 47 Hz, load shedding in the island would have to be increased. The problem would not exist when Lindisfarne-Waddamana line is completed as southern part of the system would not be islanded.

Table 10.8 System Frequency for Chapel Street Bus coupler fault (FCAS for CCGT)

Scenario	Maximum Frequency Hz	Minimum Frequency Hz	Comments
1	50.5		Island 1 Not viable
2	50.8		
3			
4	50.3	46.9	
5	50.3	46.9	
6		49.66 44.74	Island 1 Island 2
Note: 2 islands formed. 1 – North of LI with Derwent 220 kV gen; 2 – South of LI			

11. SUMMARY CONCLUSIONS OF DETAILED SIMULATION STUDIES-

The compliance to study cases under 6 scenarios is summarised in the Table 11 below.

Table 11 **NER Compliance to proposed frequency Standards**

Scenario	1	2	3	4	5	6	Comments
Generator Event							
Loss of Gunn's Unit (213 MW)	v	v	v	v	v	v	Gunns outage is less severe than Alinta
Loss of Alinta CCGT (208MW)	v	v	v	v	v	v	Alinta outage has no issues but additional reserve up to 60MW for scenario 5 & 6
Basslink event							
Loss of Basslink (500 MW) with FCSPS action	v	v	v	v	v	v	There are some issues in relation to additional load shedding may be required if FCAS is not correctly sourced
Loss of Basslink (500 MW) with failed FCSPS action	v	v	v	v	v	v	The backup UFLS operation is as per current.
Multiple contingency event							
Sheffield Bus Fault	v	v	v	v	v	v	The separation event remains unchanged as per current .but
Palmerston Bus Fault	v	v	v	v	v	v	The separation event remains unchanged as per current but inclusion of CCGT in OFGSS needs to be investigated.
Chapel Street Bus fault	v	v	v	v	v	v	The separation event remains unchanged as per current.

In summary it is concluded that:

a. The proposed changes to the frequency standard to accommodate the CCGT and other thermal units are feasible with some changes to the reserve requirements.

b. The Standard will require physical changes to settings for the UFLS in that a shift upwards by 0.5 hz will be required.

c. The reserve requirements based on the present largest contingency in Tasmania of 144 MW may need to increase by 64 MW.

d. Discrimination exists between FCSPS and OFGSS.

e. To achieve discrimination between FCSPS and UFLSS Δf/Δt (Average frequency over 300 second period) setting in the UFLSS would have to be increased to 1.2 Hz, but the rest of the settings remain as determined in the high level studies.

f. A secondary delay time will need to be set for blocks 4 to 7 to ensure that after they time out loads will be tripped to return the frequency to the regulation band under some unusual system conditions. ***.*** ***(<u>note:</u> This is not a new requirement as under some situations this will be needed even now, when load generation balance are very close after loss of generation and some load shedding)***

g. Increasing the generator contingency to 208 MW shows no particular issues with new standard on the basis that sufficient reserve is available..

h. The presence of the CCGT and other thermal units tends to increase the overall inertia and thus rate of change of frequency decreases which reduces FCAS requirement slightly

i. The presence of the CCGT also adds significant FCAS lowering capability and will assist in reducing FCSPS generation shedding quantity in many cases.

j. The reserve procurements and options are not considered at this stage, but studies shows one option of market procurement may be feasible, subject to further evaluations of other options.

k. With adequate FCAS raise set to cover loss of the largest unit in the system, no additional load was required for arming to cover tripping of Basslink in 3 out of 4 cases. In one case however about 15 MW more was required. More scenarios would have to be analysed to get a better picture.

l. While Basslink is exporting, with Thermal units providing significant FCAS lower capability, it would not be necessary to arm any more generators to maintain frequency below 52 Hz for Basslink tripping. This is dependent on Thermal generators confirming that the units are really capable of fast lower service.

m. Actual FCAS determined from studies is more than the estimated FCAS using FCAS trapeziums provided by hydro. In estimating FCAS requirement only load relief due to frequency is considered but not inertia effect.

n. If adequate FCAS is not procured to cover outage of largest unit, under frequency load shedding occurs as expected.

o. Under multiple contingencies, over-frequency is a problem with thermal sets connected as frequency goes above 52 Hz with the present operating arrangements thereby breaching the proposed frequency standard. Also CCGT would trip which may cause UFLSS to shed load, thereby not complying with NER requirement.

p. CCGT plants and other thermal plants would have to be included in OFGSS and co-ordinated to shed generation in a planned manner. In order to achieve co-ordination between CCGT and thermal plants to prevent all these units tripping simultaneously causing severe load shedding, these plants would have capability to stay connected above 52 Hz at least for a few seconds or other alternative solutions would have to be explored to resolve the over frequency issue

12. NEXT STEPS

The next stage of work involves

- Defining issues for Reserve requirement-Technical studies using full models in PSSE to be conducted to address issues raised in the detailed studies (by 24 December 07).
- Final report defining reserve quantities (5 February 2008).
- Review the findings with Alinta and agree for next stage work involving Reserve Management Market and price impact studies.

13. APPENDEX A BASE CASE LOAD FLOW DIAGRAMS

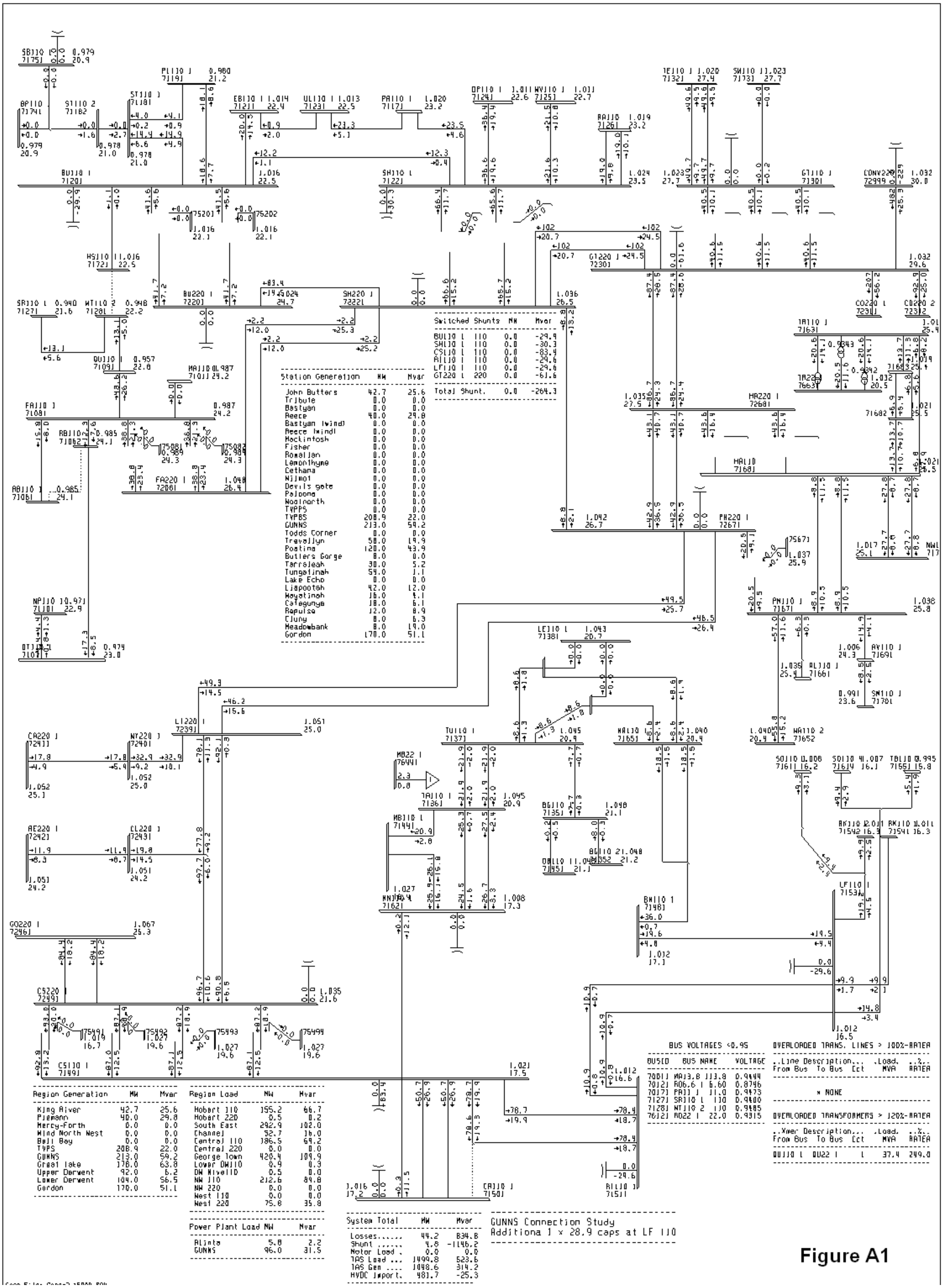
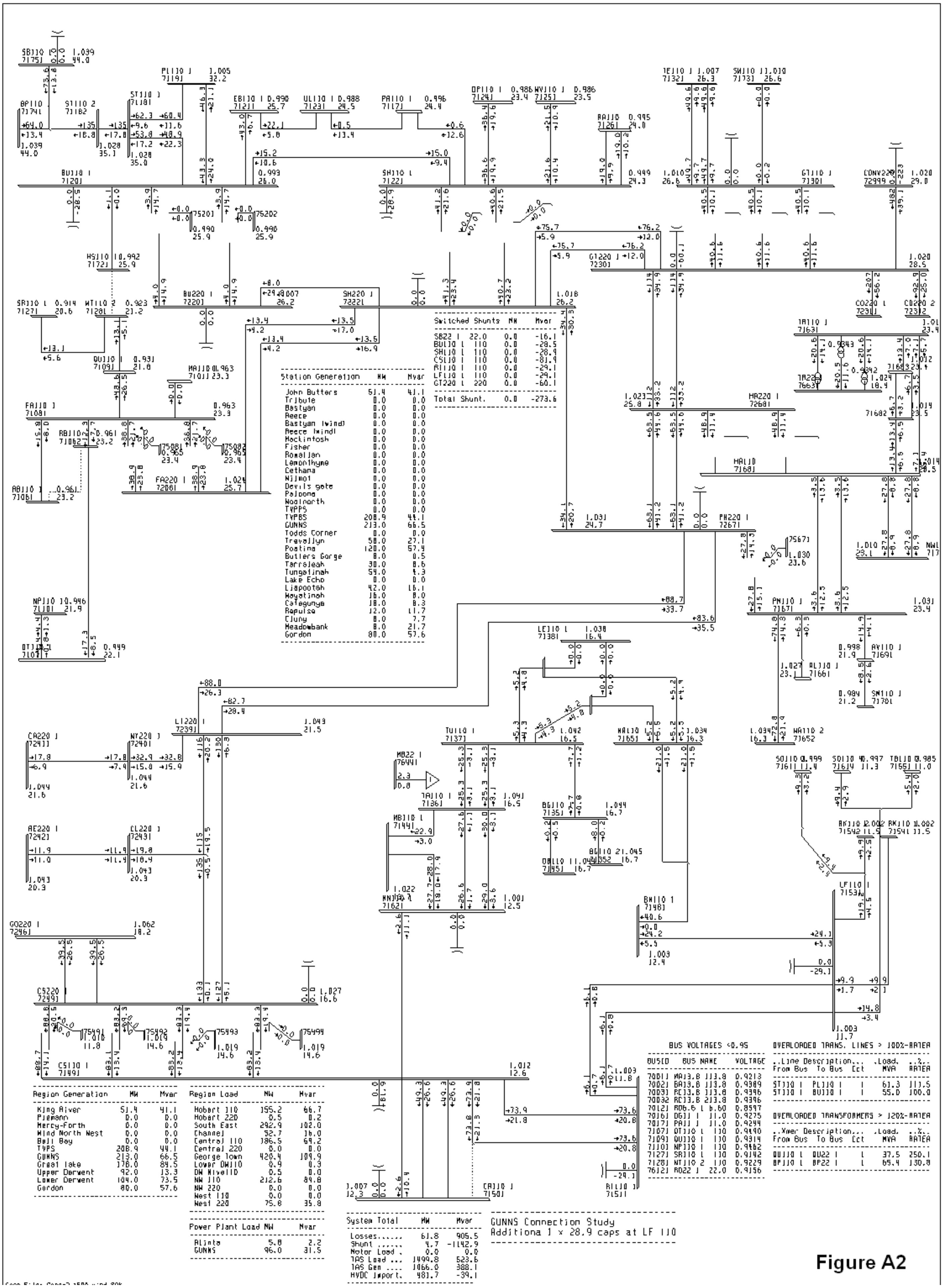

Switched Shunts MW Mvar
BUL110 1 110 0.0 -29.9
SHL110 1 110 0.0 -30.3
CSL110 1 110 0.0 -83.4
AIL110 1 110 0.0 -29.6
LFI110 1 110 0.0 -29.6
GT220 1 220 0.0 -61.6
Total Shunt. 0.0 -264.3
Station Generation MW Mvar
John Butters 42.7 25.6
Tribute 0.0 0.0
Bastyan 0.0 0.0
Reece 40.0 29.8
Bastyan (wind) 0.0 0.0
Reece (wind) 0.0 0.0
Mackintosh 0.0 0.0
Fisher 0.0 0.0
Rowallan 0.0 0.0
Lemonthyme 0.0 0.0
Cethana 0.0 0.0
Wilmot 0.0 0.0
Devils gate 0.0 0.0
Paloona 0.0 0.0
Woolnorth 0.0 0.0
TVPPS 0.0 0.0
TVPBS 208.9 22.0
GUNNS 213.0 59.2
Todds Corner 0.0 0.0
Trevallyn 58.0 19.9
Poatina 120.0 43.9
Butlers Gorge 8.0 0.0
Tarraleah 30.0 5.2
Tungatinah 54.0 1.1
Lake Echo 0.0 0.0
Liapootah 42.0 12.0
Wayatinah 16.0 4.1
Catagunya 18.0 6.1
Repulse 12.0 8.9
Cluny 8.0 6.3
Meadowbank 8.0 19.0
Gordon 170.0 51.1
Region Generation MW Mvar
King River 42.7 25.6
Pieman 40.0 29.8
Mercy-Forth 0.0 0.0
Wind North West 0.0 0.0
Bell Bay 0.0 0.0
TVPS 208.9 22.0
GUNNS 213.0 59.2
Great lake 178.0 63.8
Upper Derwent 92.0 6.2
Lower Derwent 104.0 56.5
Gordon 170.0 51.1
Region Load MW Mvar
Hobart 110 155.2 66.7
Hobart 220 0.5 0.2
South East 292.9 102.0
Channel 52.7 16.0
Central 110 186.5 69.2
Central 220 0.0 0.0
George Town 420.4 109.9
Lower DW110 0.9 0.3
DW Nivel10 0.5 0.0
NW 110 212.6 89.8
NW 220 0.0 0.0
West 110 0.0 0.0
West 220 75.8 35.8
Power Plant Load MW Mvar
Alinta 5.8 2.2
GUNNS 96.0 31.5
System Total MW Mvar
Losses...... 44.2 834.8
Shunt ...... 4.8 -1146.2
Motor Load . 0.0 0.0
TAS Load ... 1499.8 523.6
TAS Gen 1048.6 314.2
HVDC Import. 481.7 -25.3
GUNNS Connection Study
Additional 1 x 28.9 caps at LF 110
BUS VOLTAGES <0.95
BUSID BUS NAME VOLTAGE
70011 MA13.8 113.8 0.9444
70121 RO6.6 1 6.60 0.8746
70171 PA11 1 11.0 0.9473
71271 SR110 1 110 0.9400
71281 WT110 2 110 0.9485
76121 RO22 1 22.0 0.9315
OVERLOADED TRANS. LINES > 100%-RATEA
..Line Description... .Load. ..%..
From Bus To Bus Cct MVA RATEA
* NONE
OVERLOADED TRANSFORMERS > 120%-RATEA
..Xmer Description... .Load. ..%..
From Bus To Bus Cct MVA RATEA
QU110 1 QU22 1 1 37.4 249.0

Figure A1



Station Generation	MW	Mvar
John Butters	51.4	41.1
Tribute	0.0	0.0
Bastyan	0.0	0.0
Reece	0.0	0.0
Bastyan (wind)	0.0	0.0
Reece (wind)	0.0	0.0
Mackintosh	0.0	0.0
Fisher	0.0	0.0
Rowallan	0.0	0.0
Lemonthyme	0.0	0.0
Cethana	0.0	0.0
Wilmot	0.0	0.0
Devils gate	0.0	0.0
Paloona	0.0	0.0
Woolnorth	0.0	0.0
TVPPS	0.0	0.0
TVPBS	208.9	44.1
GUNNS	213.0	66.5
Todds Corner	0.0	0.0
Trevallyn	58.0	27.1
Poatina	120.0	57.4
Butlers Gorge	8.0	0.5
Tarraleah	30.0	8.6
Tungatinah	54.0	4.3
Lake Echo	0.0	0.0
Liapootah	42.0	16.1
Wayatinah	16.0	8.0
Catagunya	18.0	8.3
Repulse	12.0	11.7
Cluny	8.0	7.7
Meadowbank	8.0	21.7
Gordon	80.0	57.6

Switched Shunts		MW	Mvar
SB22 1	22.0	0.0	-16.1
BU110 1	110	0.0	-28.5
SH110 1	110	0.0	-28.9
CS110 1	110	0.0	-81.9
RI110 1	110	0.0	-29.1
LF110 1	110	0.0	-29.1
GT220 1	220	0.0	-60.1
Total Shunt.		0.0	-273.6

Region Generation	MW	Mvar
King River	51.4	41.1
Pieman	0.0	0.0
Mercy-Forth	0.0	0.0
Wind North West	0.0	0.0
Bell Bay	0.0	0.0
TVPS	208.9	44.1
GUNNS	213.0	66.5
Great lake	178.0	84.5
Upper Derwent	92.0	13.3
Lower Derwent	104.0	73.5
Gordon	80.0	57.6

Region Load	MW	Mvar
Hobart 110	155.2	66.7
Hobart 220	0.5	0.2
South East	292.9	102.0
Channel	52.7	16.0
Central 110	186.5	69.2
Central 220	0.0	0.0
George Town	420.4	109.9
Lower DW110	0.9	0.3
DW Nive110	0.5	0.0
NW 110	212.6	89.8
NW 220	0.0	0.0
West 110	0.0	0.0
West 220	75.8	35.8

Power Plant Load	MW	Mvar
Alinta	5.8	2.2
GUNNS	96.0	31.5

System Total	MW	Mvar
Losses......	61.8	905.5
Shunt	4.7	-1142.9
Motor Load .	0.0	0.0
TAS Load ...	1999.8	523.6
TAS Gen	1066.0	388.1
HVDC Import.	481.7	-39.1

GUNNS Connection Study
Additiona 1 x 28.9 caps at LF 110

BUS VOLTAGES <0.95

BUSID	BUS NAME	VOLTAGE
70011	MA13.8 113.8	0.9213
70021	BA13.8 113.8	0.9389
70031	RC13.8 113.8	0.9396
70032	RC13.8 213.8	0.9396
70121	RD6.6 1 6.60	0.8597
70161	DG11 1 11.0	0.9275
70171	PA11 1 11.0	0.9244
71071	OT110 1 110	0.9490
71091	QU110 1 110	0.9314
71101	NP110 1 110	0.9462
71271	SR110 1 110	0.9142
71281	NT110 2 110	0.9229
76121	RD22 1 22.0	0.9156

OVERLOADED TRANS. LINES > 100%-RATEA

From Bus	To Bus	Cct	Load MVA	% RATEA
ST110 1	PL110 1	1	61.3	111.5
ST110 1	BU110 1	1	55.0	100.0

OVERLOADED TRANSFORMERS > 120%-RATEA

From Bus	To Bus	Cct	Load MVA	% RATEA
QU110 1	QU22 1	1	37.5	250.1
BP110 1	BP22 1	1	65.4	130.8

Figure A2

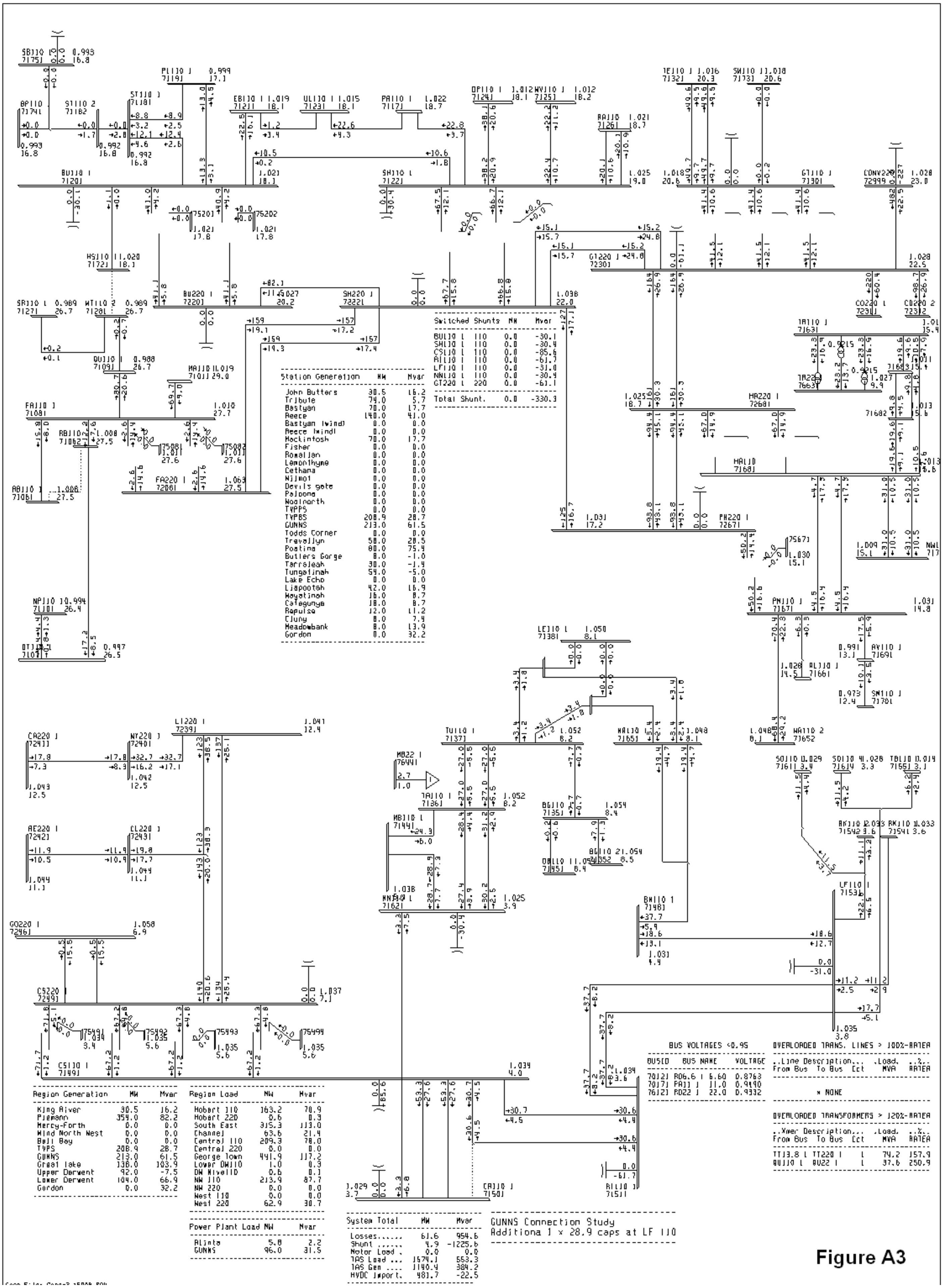
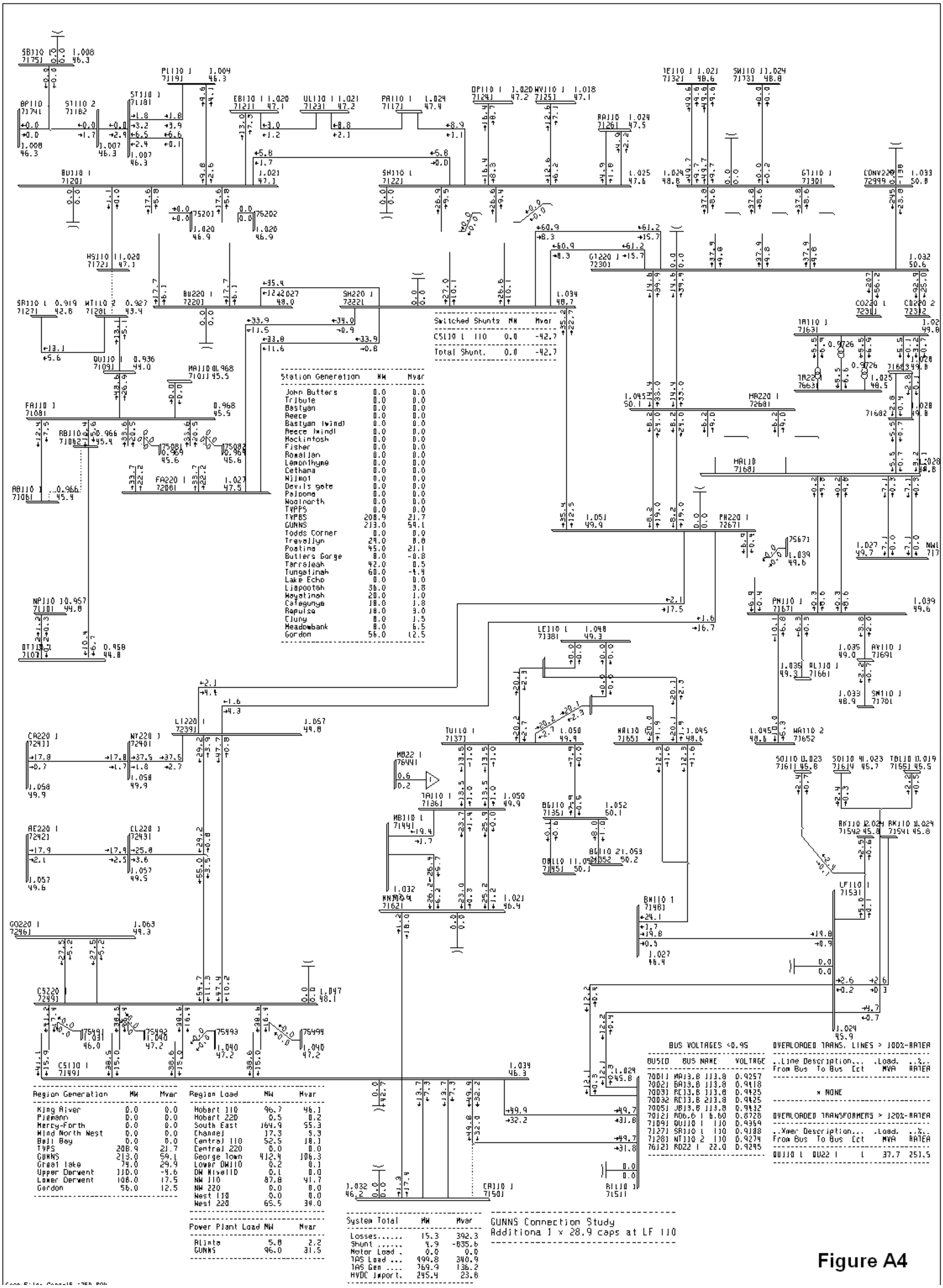

Switched Shunts MW Mvar
BUL10 L 110 0.0 -30.1
SHL10 L 110 0.0 -30.4
CSL10 L 110 0.0 -85.6
AIL10 L 110 0.0 -61.7
LFL10 L 110 0.0 -31.0
NNL10 L 110 0.0 -30.4
GT220 L 220 0.0 -61.1
Total Shunt. 0.0 -330.3
Station Generation MW Mvar
John Butters 30.5 16.2
Tribute 74.0 5.7
Bastyan 70.0 17.7
Reece 140.0 41.0
Bastyan (wind) 0.0 0.0
Reece (wind) 0.0 0.0
Mackintosh 70.0 17.7
Fisher 0.0 0.0
Rowallan 0.0 0.0
Lemonthyme 0.0 0.0
Cethana 0.0 0.0
Wilmot 0.0 0.0
Devils gate 0.0 0.0
Paloona 0.0 0.0
Woolnorth 0.0 0.0
TVPPS 0.0 0.0
TVPBS 208.9 28.7
GUNNS 213.0 61.5
Todds Corner 0.0 0.0
Trevallyn 58.0 28.5
Poatina 80.0 75.4
Butlers Gorge 8.0 -1.0
Tarraleah 30.0 -1.4
Tungatinah 54.0 -5.0
Lake Echo 0.0 0.0
Liapootah 42.0 16.9
Wayatinah 16.0 8.7
Catagunya 18.0 8.7
Repulse 12.0 11.2
Cluny 8.0 7.4
Meadowbank 8.0 13.9
Gordon 0.0 32.2
Region Generation MW Mvar
King River 30.5 16.2
Pieman 354.0 82.2
Mercy-Forth 0.0 0.0
Wind North West 0.0 0.0
Bell Bay 0.0 0.0
TVPS 208.9 28.7
GUNNS 213.0 61.5
Great lake 138.0 103.9
Upper Derwent 92.0 -7.5
Lower Derwent 104.0 66.9
Gordon 0.0 32.2
Region Load MW Mvar
Hobart 110 163.2 70.9
Hobart 220 0.6 0.3
South East 315.3 113.0
Channel 63.6 21.4
Central 110 209.3 78.0
Central 220 0.0 0.0
George Town 441.9 117.2
Lower DW110 1.0 0.3
DW Wivel10 0.6 0.1
NW 110 213.9 87.7
NW 220 0.0 0.0
West 110 0.0 0.0
West 220 62.9 30.7
Power Plant Load MW Mvar
Alinta 5.8 2.2
GUNNS 96.0 31.5
System Total MW Mvar
Losses...... 61.6 954.6
Shunt ...... 4.9 -1225.6
Motor Load . 0.0 0.0
TAS Load ... 1574.1 553.3
TAS Gen 1140.4 384.2
HVDC Import. 481.7 -22.5
GUNNS Connection Study
Additional 1 x 28.9 caps at LF 110
BUS VOLTAGES <0.95
BUSID BUS NAME VOLTAGE
70121 RD6.6 1 6.60 0.8763
70171 PA11 1 11.0 0.9190
76121 RD22 1 22.0 0.9332
OVERLOADED TRANS. LINES > 100%-RATEA
..Line Description... .Load. ..%..
From Bus To Bus Cct MVA RATEA
* NONE
OVERLOADED TRANSFORMERS > 120%-RATEA
..Xmer Description... .Load. ..%..
From Bus To Bus Cct MVA RATEA
TT13.8 1 TT220 1 1 74.2 157.9
BU110 1 BU22 1 1 37.6 250.9

Figure A3



Switched Shunts	MW	Mvar
CSL10 1 110	0.0	-42.7
Total Shunt.	0.0	-42.7

Station Generation	MW	Mvar
John Butters	0.0	0.0
Tribute	0.0	0.0
Bastyan	0.0	0.0
Reece	0.0	0.0
Bastyan (wind)	0.0	0.0
Reece (wind)	0.0	0.0
Mackintosh	0.0	0.0
Fisher	0.0	0.0
Rowallan	0.0	0.0
Lemonthyme	0.0	0.0
Cethana	0.0	0.0
Wilmot	0.0	0.0
Devils gate	0.0	0.0
Paloona	0.0	0.0
Woolnorth	0.0	0.0
TVPPS	0.0	0.0
TVPBS	208.9	21.7
GUNNS	213.0	59.1
Todds Corner	0.0	0.0
Trevallyn	29.0	8.8
Poatina	45.0	21.1
Butlers Gorge	8.0	-0.8
Tarraleah	42.0	0.5
Tungatinah	60.0	-4.4
Lake Echo	0.0	0.0
Liapootah	36.0	3.8
Wayatinah	20.0	1.0
Catagunya	18.0	1.8
Repulse	18.0	3.0
Cluny	8.0	1.5
Meadowbank	8.0	6.5
Gordon	56.0	12.5

Region Generation	MW	Mvar
King River	0.0	0.0
Piemann	0.0	0.0
Mercy-Forth	0.0	0.0
Wind North West	0.0	0.0
Bell Bay	0.0	0.0
TVPS	208.9	21.7
GUNNS	213.0	59.1
Great lake	74.0	29.9
Upper Derwent	110.0	-4.6
Lower Derwent	108.0	17.5
Gordon	56.0	12.5

Region Load	MW	Mvar
Hobart 110	96.7	46.1
Hobart 220	0.5	0.2
South East	164.9	55.3
Channel	17.3	5.3
Central 110	52.5	18.1
Central 220	0.0	0.0
George Town	412.4	106.3
Lower DW110	0.2	0.1
DW Nivel10	0.1	0.0
NW 110	87.8	41.7
NW 220	0.0	0.0
West 110	0.0	0.0
West 220	65.5	34.0

Power Plant Load	MW	Mvar
Alinta	5.8	2.2
GUNNS	96.0	31.5

System Total	MW	Mvar
Losses......	15.3	392.3
Shunt	4.9	-835.6
Motor Load .	0.0	0.0
TAS Load ...	999.8	340.9
TAS Gen	769.9	136.2
HVDC Import.	245.4	23.8

GUNNS Connection Study
Additiona 1 x 28.9 caps at LF 110

BUS VOLTAGES <0.95

BUSID	BUS NAME	VOLTAGE
70011	MA13.8 113.8	0.9257
70021	BA13.8 113.8	0.9418
70031	RC13.8 113.8	0.9425
70032	RC13.8 213.8	0.9425
70051	JB13.8 113.8	0.9432
70121	RD6.6 1 6.60	0.8728
71091	QU110 1 110	0.9359
71271	SR110 1 110	0.9188
71281	NT110 2 110	0.9274
76121	RD22 1 22.0	0.9295

OVERLOADED TRANS. LINES > 100%-RATEA

..Line Description... From Bus	To Bus	Cct	.Load. MVA	..%.. RATEA
* NONE				

OVERLOADED TRANSFORMERS > 120%-RATEA

..Xmer Description... From Bus	To Bus	Cct	.Load. MVA	..%.. RATEA
QU110 1	QU22 1	1	37.7	251.5

Figure A4

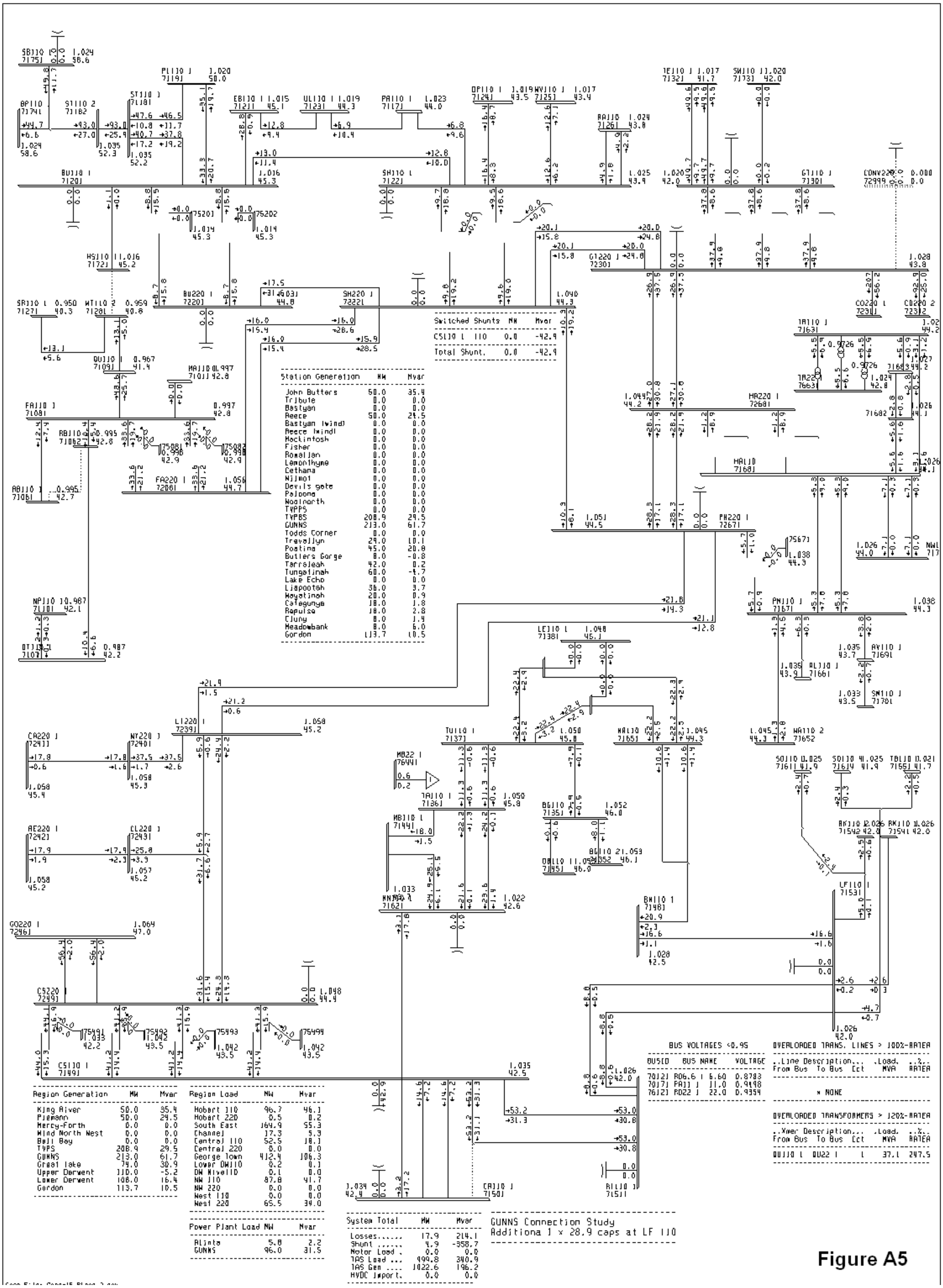

GUNNS Connection Study
Additional 1 x 28.9 caps at LF 110
Station Generation MW Mvar
Switched Shunts MW Mvar
CS110 1 110 0.0 -42.9
Total Shunt. 0.0 -42.9
Region Generation MW Mvar
King River 50.0 35.4
Pieman 50.0 24.5
Mercy-Forth 0.0 0.0
Wind North West 0.0 0.0
Bell Bay 0.0 0.0
TVPS 208.9 29.5
GUNNS 213.0 61.7
Great lake 74.0 30.9
Upper Derwent 110.0 -5.2
Lower Derwent 108.0 16.4
Gordon 113.7 10.5
Region Load MW Mvar
Power Plant Load MW Mvar
Alinta 5.8 2.2
GUNNS 96.0 31.5
System Total MW Mvar
BUS VOLTAGES <0.95
OVERLOADED TRANS. LINES > 100%-RATEA
OVERLOADED TRANSFORMERS > 120%-RATEA

Figure A5

TRANSEND HILL MICHAEL

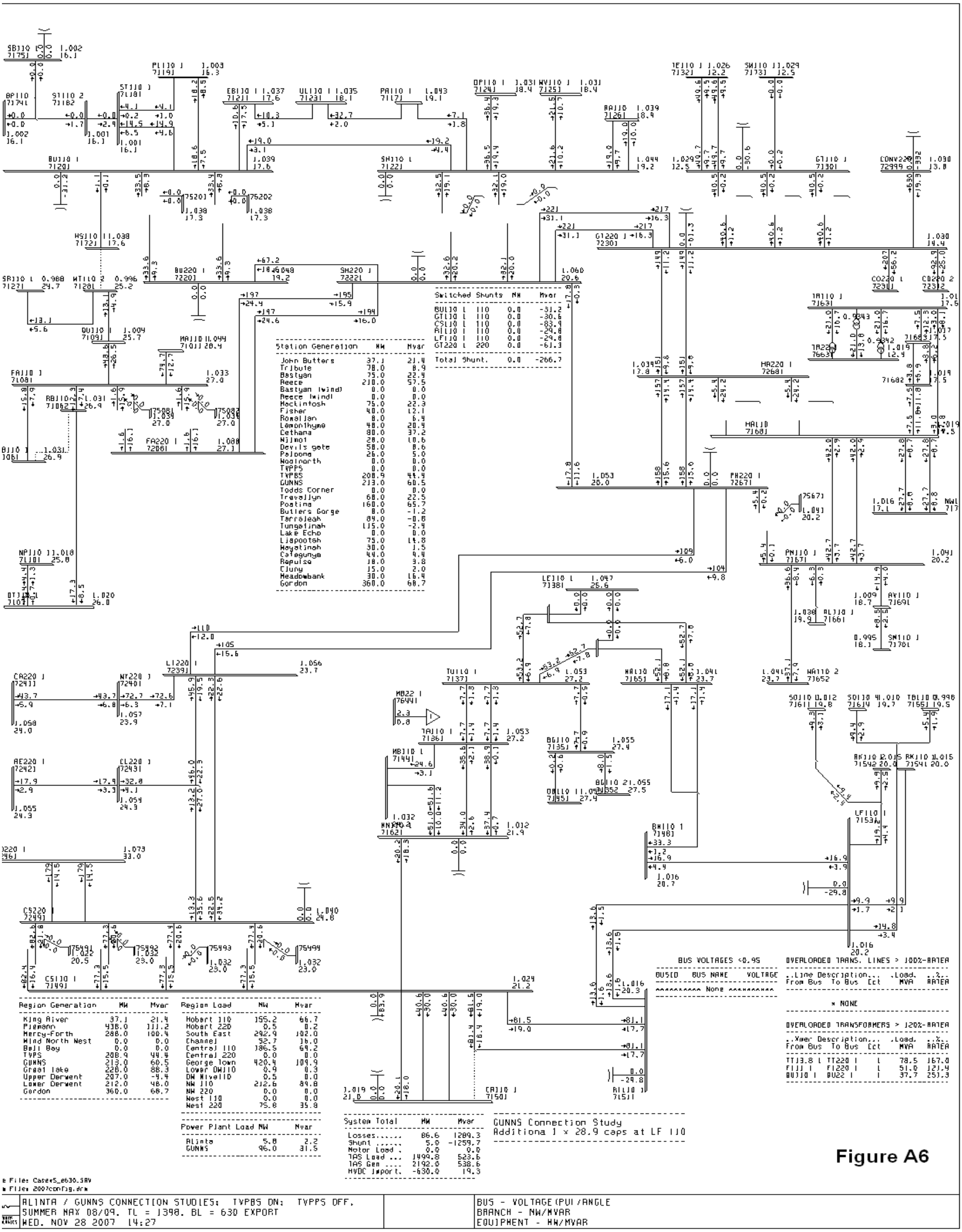


Figure A6

APPENDIX B– SCOPE OF WORK

TRANSEND

Proposal for

Alinta Limited

for

Frequency Standard Development for CCGT plant

Date of Proposal: 7 September 2007

Transend Networks Pty Ltd
1-7 Maria Street
Lenah Valley
Tasmania 7008

BACKGROUND TO PROPOSAL

Alinta is proposing to develop a 209 MW Combined Cycle Gas Technology (CCGT) plant near George Town which is planned to be connected to Transend's electricity grid at the 220 kV bus in George Town Substation. The declared plant capability does not comply with the NER frequency standards for Tasmania. Therefore, Alinta has approached Transend to investigate a frequency standard that will allow their proposed CCGT plant to be connected to the grid. Additionally, as the size of the unit proposed is significantly bigger than the largest unit in Tasmania (144 MW), Alinta has requested Transend to assess a level of additional reserve that will be required to dispatch such a unit.

This proposal sets out;

- a scope of work which will be undertaken by Transend,
- the proposed approach for the investigations,
- the deliverables and proposed timeframes,
- resources required to undertake the project, and
- commercial terms and conditions which will apply.

The frequency standard currently in place is given in Appendix B.

15. SCOPE OF WORK

Transend under this consultancy study will undertake the following tasks:

1.1 Frequency Standard Development

- Document and define a standard for the CCGT plant, based on information provided by Alinta .
- Review the existing UFLS scheme (assuming no changes to Basslink Frequency Controlled Special Protection Scheme (FCSPS) settings) to comply with the standard developed above, and recommend new settings.
- Review the OFGSS including changes to FCSPS and recommend new settings.

1.2 Reserve Management Studies

- Document the range of issues and reserve requirements which result from the revised standard and increased plant size.
- Identify options and quantify requirements for sourcing reserves for a unit size of 220 MW.

16. PROJECT APPROACH

The project work will be carried out in five stages. The stages will not necessarily be undertaken in a sequential manner because some of the issues are interdependent and therefore it may be beneficial and efficient to address them together.

FREQUENCY STANDARD DEVELOPMENT

STAGE I DOCUMENT AND DEFINE A STANDARD FOR THE CCGT PLANTS

The scope of this work involves documenting the characteristics of the CCGT plant in consultation with Alinta. Essentially it is intended that Alinta will provide a range of capability including a preferred position. The information will be reviewed and put in a format suitable for defining the frequency standard.

STAGE 2 HIGH LEVEL STUDIES:

(a) Determine UFLS requirements (no change in FCSPS)

This work assumes that the existing FCSPS scheme will not be altered in determining the under frequency load shedding requirements. It is to be noted that the work largely involves determining Under Frequency Load Shedding (UFLS) block sizes and its location within the frequency operating band to meet the standard defined in Stage 1.

Simulations will be carried out under a number of future dispatch scenarios over a 10 years timeframe to assess load shedding schemes to ensure that frequency stays within the standard. This will be carried out using high level simulations using inertia approach. The current relay operating times and block sizes will be used.

(b) Review the UFLS requirements taking into account of OFGSS and changes to FCSPS

This work will be undertaken as per (a) above except that the UFLS will be reviewed by assuming that FCSPS scheme changes are possible. Essentially there are two issues relating to the FCSPS scheme:

- The maximum time delay required is currently set as 630mS based on several equipment switching time requirements (including signal time). This will be reviewed, and reduced if required, to accommodate discrimination between FCSPS action and the UFLS scheme.
- The second issue is to review if the quantity of load that is to be shed needs to be modified as a result of revised frequency standards.

Stage 3 Detailed simulation

This stage involves carrying out detailed simulations using all models (Transmission Network, Basslink, Power plant characteristics including all control systems – excitation and governor systems) against a range of generation and demand scenarios.

Both generator and load tripping will be simulated using PSSE simulation software to assess the frequency performance based on the settings determined from the high level studies in Stages 2 and 3. The results from this simulation will be used to fine tune the settings.

If required, based on the work undertaken in stage 3, FCSPS and/or OFGSS settings will be modified to maintain frequency within the proposed standard. Any major issues identified will be documented at this stage.

2.2 Reserve Management Studies

Stages 4 and 5 largely address the issues surrounding reserve procurement and identify a range of solutions. It is to be noted the scope for this part of the study is hard to define until Frequency Standard Development studies under Stages 1 – 3 are completed. Even then the scope will evolve as a number of assumptions have to be made about how NEMMCO dispatches reserve. In addition, some of the commercial issues may cloud it.

Stage 4 Document issues

Transend will prepare a document on reserve requirements resulting from revised standard and increased plant size including all assumptions and issues with a view to getting approval of the scope for simulation.

Stage 5 Simulation of various options

This stage of work involves using the detailed simulation models developed in Stage 3 to establish the standard which will be used to conduct a range of studies to address the issues raised in Stage 4.

Several options that are able to address the increased reserve requirement due to increased generation size will be simulated. The simulation work involves conducting runs using PSSE including all the models –Transmission, generator (including exciter, governor), Basslink and relay characteristics. The approach taken here is to conduct a number of generator and load trippings, to assess and define reserve requirements for a 144MW unit (presently the largest unit) and Alinta's proposed CCGT size unit.

This stage also involves identifying and conducting simulations with a range of potential solutions:

- Alinta providing reserve with its own SPS load shedding as reserve (similar to FCSPS scheme for Basslink);

- Alinta dispatching its own reserve using the open cycle plant as reserve provider ;
- Procuring reserve from the market ;
- A combination of 1&2 and possibly 3.

It should be noted that no attempt will be made to determine the value of reserve or price impacts in this study. This part of the work will give a relative estimate of MW additional reserve required against a limited range of predefined demand/generation /Basslink scenarios.

The purpose of this study is to give an indicative range of potential magnitude in increased reserve for the plant size assumed, this will allow Alinta to assess the magnitude of the issue and to be informed on the options available to address it.

This will also provide Alinta with the information required to assess the estimated economic costs of the alternatives.

2.3 DELIVERABLES AND TIMING

Frequency Standard Development

Stage I written report of required standard based on Alinta's plant capability.

Stage 2 written report observing high level studies and proof of concept of frequency standard.

All work under Stages 1 and 2 will be completed by 31 October 2007

Stage 3 combined standard from detailed simulations

All work under Stage 3 will be completed by 31 December 2007

Reserve Management Studies

A report for Stages 4 and 5 including detailed analysis covering all aspects will be provided. This will provide Alinta with the information required for it to calculate the economic costs of the alternatives.

Stage 4 issues document and defined scope.

Stage 5 final report from simulation studies.

All work under Stages 4 and 5 will be completed by 31 March 2008.

17. RESOURCES

PERSONNEL

Project Manager	Dr. Chandra Kumble
Project Analyst	Mr Prahlad Tilwalli
External Review	Doug Clarke

APPENDIX B – AEMC FREQUENCY STANDARD FOR TASMANIA

The following table applies to any part of the Tasmanian power system, other than an island:

Table 1: Determination as to the Tasmanian frequency standards

CONDITION	CONTAINMENT	STABILISATION	RECOVERY
Accumulated time error	15 seconds		
No contingency event or load event	49.75 to 50.25 Hz, 49.85 to 50.15 Hz 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Load event	49.0 to 51.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Generation event	47.5 to 51.0 Hz	49.85 to 50.15 Hz within 5 minutes	
Network event	47.5 to 53.0 Hz	49.0 to 51.0 Hz within 1 minute	49.85 to 50.15 Hz within 5 minutes
Separation event	46 to 55 Hz	47.5 to 51.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	46 to 55 Hz	47.5 to 51.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

Table 2: Determination as to the frequency standards for islands within Tasmania

CONDITION	CONTAINMENT	STABILISATION AND RECOVERY	
No contingency event, or load event	49.0 to 51.0 Hz		
Generation event or network event	47.5 to 53.0 Hz (Note)	49.0 to 51.0 Hz within 5 minutes	
Load event	47.5 to 53.0 Hz (Note)	49.0 to 51.0 Hz within 10 minutes	
The separation event that formed the island	46 to 60 Hz	47.5 to 53.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes
Multiple contingency event including a further separation event	46 to 60 Hz	47.5 to 53.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes

Note Where it is not feasible to schedule sufficient frequency control ancillary services to limit frequency excursions to within this range, operation of the UFLSS or OFGSS is acceptable on the occurrence of a further contingency event.

APPENDIX C – UFLSS SETTINGS CALCULATION

The UFLS has been designed considering either the loss of a large amount of generation and/ or the loss of Basslink under high import with the failure of the FCSPS. Under these conditions the rate of change of frequency would be very high and the time available for load shedding would be less than a couple of seconds. During this period hydro generator governor action would be ineffective in pulling system frequency up as their response is slow. So, the only significant mechanism available for limiting frequency deviation is load shedding. This appendix sets out the design criteria and the design calculation for determining the new frequency settings of the UFLSS to meet the proposed frequency standards.

Design criteria

- the scheme should discriminate between credible and non-credible contingencies and shed load only for non-credible contingencies.
- the scheme should be robust enough to maintain the frequency standard for different Tasmanian system configurations:
  - Tasmanian system interconnected with the mainland through Basslink;
  - Tasmanian system islanded with Basslink out of service; and
  - Tasmanian system split into a number of islands.
- the scheme should allow for the FCSPS to act before the UFLS scheme becomes effective.
- the scheme should operate as a backup for failure of the FCSPS scheme.
- the settings should be such as to achieve discrimination. That is, the next block should not trip before the block which has picked up sheds the load for rate of change of frequency up to 2 Hz/second.
- the scheme should limit over shedding of load to limit the over frequency to around 51 Hz.
- The scheme should meet the Jurisdiction Co-ordinator (JC) priority schedule.
- The scheme should allow the frequency to recover within the times indicated in the Tasmanian frequency standards.

Design Calculation

The UFLS scheme is not expected to operate for a credible contingent event resulting in loss of generation. It is expected to operate for a separation event or for a multiple contingent event resulting in loss of generation and maintain system / island frequency above 46 Hz. So frequency setting for UFLS scheme is set between 47.4 Hz and 46.1 Hz

In the proposed modified frequency standard, the frequency range available for load shedding is between 48 Hz and 47 Hz, a band width of 1 Hz as against 1.5 Hz (46 to 47.5 Hz) in the current UFLSS. So if the existing 7 blocks are to be maintained, the difference in frequency settings between two blocks would have to be reduced without losing discrimination.

Discrimination

Discrimination means that next load shedding block should not pick before the block that is already picked sheds load. Discrimination depends on the rate of change of frequency, circuit breaker opening time, relay accuracy and steps available for relay settings.

The relays installed have an accuracy of ± 0.01 Hz and frequency can be set in steps of 0.01 Hz. Records show that CB opening time for most of the breakers used for shedding load is 80 msec and those breakers which have higher opening time are assumed to be replaced.

Initial rate of change of frequency was estimated using system inertia, system load and Basslink imports. The estimated df/dt does not exceed 2.0 Hz for the system considered. Therefore to achieve discrimination frequency difference required is given by equation:

$$\Delta f = df/dt * \text{CB opening time} + \text{error in measurement}$$

$$= 2.0 * 0.08 + 0.02$$

$$= 0.18 \text{ Hz}$$

So, in determining settings Δf is assumed to be 0.2 Hz for the first 3 blocks. With the first 3 blocks of load shed df/dt would significantly be lower therefore for the remaining blocks Δf is assumed to be 0.1 Hz. The frequency setting for the first block is set at 47.95 Hz to allow for safety margin.

This will have to be reviewed for more extreme events in the detailed modelling.

Discrimination with FCSPS

UFLS scheme also acts as a back up for FCSPS. Therefore, FCSPS should not pick before FCSPS picks up. The worst operating time for FCSPS is 0.65 seconds. So the first block of UFLS would pick up before FCSPS provided rate of change of frequency is greater than:

(50 Hz - Pick up frequency setting of df/dt relay for zone 1) / difference in time between FCSPS operation and Measurement time to determine average rate of change of frequency i.e. (50 – 49.0) / (0.65 -0.3) = 2.86 Hz

So, for the first block of UFLSS to pick up before FCSPS df/dt would have to be greater than 2.86 Hz. The studies show that maximum df/dt does not exceed 2Hz/second. So discrimination can be achieved with FCSPS with the proposed settings.

The amount of load contracted to shed when Basslink trips while exporting may have to be increased. This needs to be investigated. This is a reserve issue. It will have to be covered under FCAS.

This will need to be reviewed for more extreme events in the detailed modelling.

Rate of change of frequency settings

Rate of change of frequency relays are used to enable load shedding early to speed up frequency recovery when rate of change is very high. Often it is possible to shed one block load less. Transend has set a df/dt setting of 1 Hz /second With 1 Hz /sec load would be shed 0.7 seconds earlier. With very high df/dt there is not much advantage because of 0.34 seconds required to measure average df/dt. NEMMCO has objection to use of df/dt because when load is actually shed frequency would be less than the back up frequency setting. It appears that customers complain about it without realising that the load would be shed even without df/dt relay but with some delay. It is possible to do away with df/dt without any problems.

Rate of change of frequency (df/dt) relay

Transend uses df/dt relay to shed load early in the event of loss of large generation. This relay measures average rate of change of frequency over a definite time. The measurement starts after a set frequency reached. The relay picks if measured frequency deviation in the measurement time is above a set limit.

Transend uses df/dt measurement and back up frequency setting for first two blocks. The pick-up frequency for measurement, measurement time and back up frequency for all 7 blocks are listed in Table 2.

Effectiveness of df/dt relay

It is possible for the back up frequency relay to pick-up earlier than df/dt relay due to measurement time set to calculate average frequency. For this to happen, df/dt has to be greater than:

(pick-up frequency for df/dt measurement - back-up frequency setting) / Measurement Time

So, block 1 back-up frequency will pick up before, if rate of change of frequency is greater than 0.366 Hz/second [(48.5 - 47.4 Hz) / 0.3] and block 2 back-up frequency will pick up before if rate of change of frequency is greater than 0.33 Hz/sec [(48.2 - 47.2) / 0.3]. For this to happen generation loss would have to be higher than approximately 37% of system load (2H*(df/dt) = 2 * 5 *3.66 pu), assuming system inertia constant of 5 MW-sec/MVA on **SYSTEM MVA BASIS**. If inertia is lower, back-up frequency will pick up when loss of generation is lower. This only means that df/dt relay is not effective when rate of change of frequency is very high.

Loss of Discrimination

With CB opening time of 0.08 sec and measurement error of 0.02 Hz, the rate of change of frequency at which next block would pick up are given in table 1. This is calculated using the formula:

(pick up frequency for the block picked – pick up frequency for the next block – measurement error) / 0.08

Block No	df/dt: For next zone to pick up Hz/sec
2	2.25
3	2.25
4	2.25
5	1.00
6	1.00
7	1.00

Table 1: Rate of change of frequency for losing discrimination

From the table above it can be inferred that there is a possibility of block 2 picking up before block 1 is shed if the rate of change of frequency is higher than 2.25 Hz. This is not much of an issue as the next block would be shed in any event because of the large generation loss.

Discrimination is maintained between the other blocks as the rate of change of frequency would be lower as a result of the load which had already been shed.

Selection of load for shedding

The loads selected in the load shedding blocks must meet Jurisdictional Co-ordinator priority shedding schedule.

Block size and no. of blocks

In the current scheme, block sizes are selected to limit over shedding such that frequency does not go above 51.0 Hz. Performance would be better with new settings as load would be shed earlier because frequency settings have been raised. With the current settings there were a few cases where frequency overshot a little over 51.0 Hz (but never 52 Hz)).

Distribution of loads

The loads are distributed such that in the event of the Tasmanian network splitting into islands the frequency standard is maintained. There are however some instances of islanding where it is not possible to maintain frequency because of a large shortfall in generation. In such cases the island would be blacked out.

UFLSS Settings

The frequency settings for different blocks based on parameters required to achieve discrimination, are given in table 2.

Block No	df/dt: pick-up Frequency (Hz)	df/dt: freq deviation (Hz)	df/dt: measuring time (sec)	f: pick-up Frequency (Hz)
1	49.0	0.30	0.34	47.95
2	48.8	0.30	0.34	47.75
3	0.0	0.00	0.00	47.55
4	0.0	0.00	0.00	47.35

5	0.0	0.00	0.00	47.25
6	0.0	0.00	0.00	47.15
7	0.0	0.00	0.00	47.05

Table 2 Proposed UFLS settings