SINCLAIR KNIGHT MERZ
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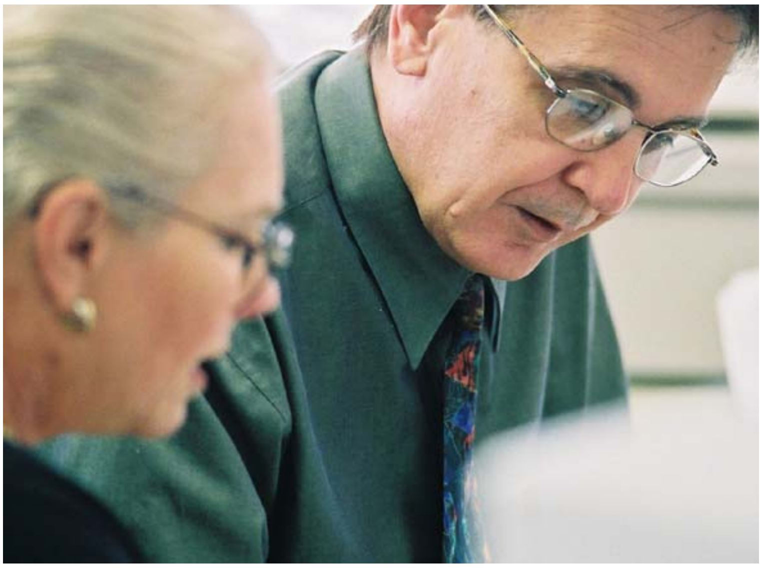
imo
Independent Market Operator

Ancillary Service Standards and Requirements Study



FIRST DRAFT REPORT

- Rev1
- 16 April 2009

Ancillary Service Standards and Requirements Study

FIRST DRAFT REPORT

- Rev2
- 16 April 2009

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1. Executive Summary

Sinclair Knight Merz (SKM) has been engaged by the Independent Market Operator (IMO) to undertake this report into the treatment of Ancillary Service within the Wholesale Energy Market (WEM). The report is to meet the requirements of clause 3.15.1 of the Wholesale Energy Market Rules (Market Rules). This report is a first draft and is intended as a basis for the first round of public consultation.

The treatment of Ancillary Services in the Market Rules is analysed and compared to Markets in the Australian National Energy Market (NEM), Ireland, Singapore, New Zealand and Great Britain, with particular attention given to Irish market that has many similarities to the WEM. Through this process, observations are drawn for areas where the treatment of Ancillary Services could be revisited to better meet the Market Objectives.

To quantify the benefit of recommended changes, two studies have been undertaken. The first study investigates the ability of the South West Interconnected System (SWIS) to respond within the frequency parameters set out in the Technical Rules for the South West Interconnected Network (Technical Rules), under a range of Ancillary Services treatments. The second study models an Optimised Dispatch Market for the SWIS to quantify possible improvements in the economic outcomes of the WEM and provide a Monte Carlo based reflection of Unserved Energy.

The resulting recommendations and key benefits (in italics) are as follows:

1) No change to the Market Rules regarding the definition of Ancillary Services is recommended at this time. *Existing definitions effectively cover all Ancillary Services for the WEM as it exists today.*
2) No change to the Market Rules in the determination of Load Following is recommended at this time. *The existing determination criteria can adequately respond to changes in the market.*
3) The Market Rules on the determination of Spinning Reserve be revisited to reflect "performance based" criteria as in the Technical Rules. *Although the current determination is the economically optimal and lowest technically acceptable volume of spinning reserve, this change will allow the determination of Spinning Reserve to be optimised as generation parameters on the WEM change.*
4) No change to the Market Rules in the determination of Load Rejection Reserve Services is recommended at this time. *The existing determination criteria can adequately respond to changes in the market.*
5) The Renewable Energy Generation (REG) working group review the use of common machines to supply Load Following and Spinning Reserve services in the context of increased wind generation within the WEM. *With the increase in wind generation penetration on the SWIS, the risk of a concurrent Load Following and Spinning Reserve event will increase.*

6) Develop the Ancillary Service procurement mechanism to ensure adequate quantities of generation with the required capabilities are available. *Studies demonstrate that the introduction of a mid-merit generators (higher efficiency simple cycle gas turbines eg LMS100) would decrease the cost of the Optimised Dispatch Market by over $30 million per annum and increase the security of supply. At the moment there are limited market mechanisms to support Non-Verve Energy Generators in the development of these technologies.*
7) Changes should be made in order to reduce the reinforcement of the dominance of Verve Energy in the provision of Ancillary Services. *Studies demonstrate that procuring Spinning Reserve and Load Following from all existing market participants will decrease the cost of the Optimised Dispatch Market by $16 million per annum whilst improving system security. This would be achieved with no additional capital investment.*
8) A real time market for the procurement of Ancillary Services is not implemented at this time. E*vidence concludes that a full real-time market for Ancillary Services in the SWIS would result in a suboptimal outcome.*
9) No recommendation has been made on the basis for setting the price for Ancillary Services (however alternatives have been provided); information received in the first round of public consultation will inform this recommendation. *Further stakeholder feedback is sought.*
10) A Standard Form Agreement with standard specifications for the provision of each of the Ancillary Services should be developed as soon as possible. *SKMs current view is that this likely to be the most cost effective solution.*
11) Implementation of a penalty regime for failure to provide a declared Ancillary Service is recommended. *Based on results of international comparisons.*

Alternatives are provided to each of the recommendations to facilitate the public consultation process.

For completeness, a range of options for the improvement to the delivery Ancillary Services through the WEM energy market, particularly the balancing market, are also provided. However, feedback on these issues is not sought through the consolation process.

2. Introduction

2.1. Scope of Report

The scope of this report is to review the Ancillary Services Definitions, Service Standards, and Determination and Procurement Requirements, as set out in sections 3.9, 3.10 and 3.11 respectively of the Market Rules (but excluding System Restart which is outside the scope of the study), herein referred to as the Ancillary Service market mechanisms.

This report is to meet the requirements of clause 3.15.1 of the Market Rules.

Specifically, the scope of the report is to examine the current standards and requirements including:

- A review of the appropriateness of the Ancillary Service Provisions in sections 3.9, 3.10 and 3.11 of the Market Rules.
- A technical analysis as to whether the Ancillary Service Provisions achieve a Best Practice outcome in regard to addressing the Wholesale Energy Market (WEM) Objectives.
- A technical and financial benchmark analysis as to whether the Ancillary Service Provisions achieve a Best Practice outcome in regard to Ancillary Service Definitions, Standards, Determinations and Requirements in other comparable Electricity Markets.
- Proposed amendments to the Ancillary Service Provisions in the Market Rules, in order to achieve a Best Practice outcome.
- If amendments are proposed, an assessment of how these amendments will facilitate the Market Rules in order to better address the market objectives.
- Cost benefit analysis of any proposed amendments compared to the current standards and provisions.
- The consideration of black start generation has been specifically excluded from the scope of this report.

Additional analysis that follows the report “Investigation into the power system incident of November 2007” has been undertaken to determine:

- Whether the requirements placed on System Management in regard to the quality of Ancillary Services in the Market Rules are adequate or could be improved.
- Whether the Market Rules, or System Management’s Power System Operating Procedures, should be more detailed in regard to the type of plant used for Spinning Reserve in the SWIS.
- An examination of the dynamic performance of the SWIS, in conjunction with System Management.

2.2. Structure of Report

This report is structured into three sections:

- Main Report Body.
- Study 1: System Frequency Response Modelling.
- Study 2: Market Economic Modelling.

The main body of the report commences with a background to the report followed by a common definition of Ancillary Services. The report uses these definitions to describe the existing requirements surrounding Ancillary Services in the WEM and to compare these requirements to those in other markets. Section 7 provides a summary of stakeholder interviews. Section 8 takes information from the preceding sections and further details the major issues identified with the existing Ancillary Service treatments.

At relevant points throughout the report, key observations are drawn out in a blue box; these form the basis for the recommended changes to Ancillary Service Requirements in the WEM.

Study 1 and Study 2 detail the analysis that quantifies the benefits to the WEM of the key recommendations.

3. Background

3.1. SWIS System Background

The SWIS operates in the South West of Western Australia in an area bound by the towns of Geraldton, Kalgoorlie and Albany. The system is isolated from the interconnected power systems of eastern and southern Australia and is unlikely to be electrically interconnected to these systems in the foreseeable future.

The SWIS is a relatively small power system by international standards, having a peak demand in the order of 3800 MW and installed capacity in the order of 5000 MW. In international comparisons it therefore bears, in many respects, a close resemblance to medium sized “island” systems.

3.2. Ancillary Services in the SWIS

The purpose of the Ancillary Services market mechanisms is to ensure the SWIS can adequately respond to real time changes in load and generation under a range of operating scenarios.

Ancillary Services for the SWIS are procured by System Management on behalf of the IMO, consistent with the requirements of the WEM Market Rules. System Management currently has Ancillary Service contracts in place with two Market Customers, to supply Spinning Reserve as System Interruptible Load (SIL). The remainder of Ancillary Services are provided by Verve Energy under the requirements of the Market Rules.

3.3. Market Rules Requirements

The Market Rules guide the operation of the WEM and are made effective by the Electricity Industry (Wholesale Electricity Market) Regulations 2004. The WEM is administered and operated by the IMO in accordance with the Market Rules.

Sections 3.9, 3.10 and 3.11 of the Market Rules currently guide the procurement of Ancillary Services on the WEM.

This report is to meet requirements within the WEM Market Rules, specifically 3.15.1.1 and 3.15.2. Through these sections, the Market Rules require this study to include:

(a) Technical analyses determining the relationship between the level of Ancillary Services provided and the SWIS Operating Standards as set out in clause 3.1.

(b) Identification of the expected costs that would result from an increase in the requirements for Ancillary Services due to additional Facilities connecting to the SWIS.

(c) A cost-benefit study on the effects on stakeholders of providing and using a variety of levels of each Ancillary Service.

3.4. Market Objectives

The operation of the Ancillary Services market mechanisms must best meet the Wholesale Market Objectives outlined below.

1) To promote the economically efficient, safe and reliable production and supply of electricity and electricity related services in the SWIS.
2) To encourage competition among generators and retailers in the SWIS, including facilitating efficient entry of new competitors.
3) To avoid discrimination in that market against particular energy options and technologies, including sustainable energy options and technologies such as those that make use of renewable resources or that reduce overall greenhouse gas emissions.
4) To minimise the long-term cost of electricity supplied to customers from the SWIS.
5) To encourage the taking of measures to manage the amount of electricity used and when it is used.

The purpose of the Ancillary Services processes is to ensure the reliable production of supply on the SWIS by ensuring the system can adequately respond to real time changes in load and generation under a range of scenarios. As such, the Ancillary Services market mechanisms are critical to meeting Objective 1.

Conversely, Ancillary Services procurement directly affects the manner in which generation is scheduled in the WEM. As such, the Ancillary Services procedures can have a direct effect on the economic efficiency of the market and therefore the long–term cost of electricity supplied to customers.

Finally, not all generators and loads provide the same level of response to system events; in effect offering varying levels of service in the provision of Ancillary Services. Objective 2 demonstrates a preference for market mechanisms to be employed to establish the optimal cost / service level for Ancillary Services from existing and new facilities.

As such, the Ancillary Services processes have a material impact on the WEM and its ability to achieve the Market Objectives.

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3.5. System Event of November 2007

Included in the scope is consideration of the recommendations of the PA Consulting report titled "Investigation into the power system incident of November 2007". This report was the result of an investigation into a system event on 28 November 2007 where the system did not adequately respond after the failure of a single generator. The recommendations of the report were as follows:

1) System Management immediately review the use of each plant type for the provision of Spinning Reserves, taking into account the demonstrated performance of each plant type.
2) System Management immediately prepare an Ancillary Services Specification which sets out the expected performance of participants' plant that is to provide Ancillary Services.

   All plant that supply Ancillary Services be tested to verify the performance of that plant against the System Management Ancillary Services Specification.
3) System Management immediately review
   - The performance of the Automatic Governor Control (AGC) system during the incident of 28 November.
   - The continued use of the AGC under low frequency conditions.
   - The monitoring of the performance of the AGC and controlled plant to set it on a formal basis.
4) The IMO undertake a study of the Ancillary Service Standards and the basis for setting Ancillary Service Requirements under Clause 3.15.1 of the Market Rules.
5) System Management take an active interest in the dynamic performance of the SWIS, recognising that it is the responsibility of System Management to ensure the reliable and secure operation of the SWIS, by either:
   - Having an dynamic analysis capability within System Management, or
   - Having regular discussions with any provider of such capability, such as Western Power Networks, under a service agreement that places the obligation on the provider to provide prompt support to System Management requests.
   - These recommendations have been taken into account in the analyses undertaken in this report.

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4. General Overview of Ancillary Services

4.1. Background

Eurelectric defined Ancillary Services generally as '*all services required by the transmission or distribution system operator to enable them to maintain the integrity and stability of the transmission or distribution system as well as the power quality'*[1]. Ancillary Services are essential for the safe and reliable operation of the wholesale energy market including power system restoration in case of blackout. They are driven by system operational performance requirements, its needs constantly changing with system conditions, and are normally treated outside the main energy market.

Historically, in most electricity sectors, electricity utilities were vertically integrated, owning and operating the whole chain of electricity provision from generation through transmission to distribution and supply. In such non-deregulated environments, the single utility is responsible for system operation and Ancillary Services are typically not unbundled and provided by the company's own assets.

However, with electricity market liberalisation, the activities of the vertically integrated utility – generation, transmission, distribution, supply – are unbundled, with special emphasis on unbundling the monopolistic (transmission, distribution) and competitive (generation, supply) segments in order to achieve greater efficiency and transparency. In most liberalised markets Ancillary Services are also unbundled and open to market provision in order to achieve efficiencies by the introduction of competition in its procurement and provision and also greater transparency and accountability.

Every deregulated electricity market must attempt to achieve an optimal approach to the provision of Ancillary Services as part of its inherent design. However, unique generation sector legacies, system characteristics, transitional regimes and network considerations have often resulted in distinct electricity market arrangements for Ancillary Services, even in jurisdictions with common main market design principles. Definitions and detailed characteristics of Ancillary Services are therefore inconsistent between markets, which does not facilitate the direct comparison between arrangements internationally.

Notwithstanding the above, there are certain generic Ancillary Services needs that, due to its dominant technical nature, are required for the safe operation in all markets. In order to facilitate the comparison between Ancillary Services arrangements in various markets worldwide and those

[1]Ancillary Services . *Unbundling Electricity Products –an Emerging Market*. Thermal Working Group, EURELECTRIC.

in the SWIS, the following section describes key Ancillary Services which are later used in the description of Ancillary Services arrangements in various jurisdictions.

4.2. A Common Definition of Key Generic Ancillary Services

As discussed in 4.1, the naming and definition of Ancillary Services in deregulated markets is inconsistent. In order to compare the provision of Ancillary Services across a number of different markets, essential Ancillary Services that are commonly found across all markets have been classified into broad "functional" groups. Based on the common operational requirements of power systems there are three main types of essential Ancillary Services, namely Reserve, Voltage Control and Black Start. Reserve is by far the most important Ancillary Services technically and financially in electricity markets. It is therefore useful to further distinguish the main reserve into further subcategories due to the difference in their technical characteristics and potential providers. The characterisation of essential Ancillary Services presented in Table 4.1 divides the main forms of Ancillary Services into six categories by splitting Reserve into four main types.

In some markets, certain Ancillary Services types shown in Table 4.1 are consolidated into a single service whereas other Ancillary Services types could be found further broken down into a number of specialised services. In the broad characterisation presented below a generic terminology is used to compare in later sections the main "typical" ancillary grid services found across different market structures and designs[2]. For clarity the corresponding WEM Ancillary Service definition is provided in italics.

[2] 'Loads Providing Ancillary Services: Review of International Experience' Ernest Urlando Lawrence Berkeley National Laboratory, May 2007

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▪ Table 4.1 Typology of essential Ancillary Services

<table>
<tr><th colspan="3">Ancillary Service</th><th>Description</th><th>Response speed</th><th>Duration</th><th>Dispatch frequency</th></tr>
<tr><td rowspan="4">Reserve</td><td>Continuous Regulation (Load Following)</td><td rowspan="2">Normal operation</td><td>Provided by online resources with automatic controls. Track and correct minute-to-minute fluctuations in load and output.</td><td>< 1 minute</td><td>Minutes</td><td>Hours to days</td></tr>
<tr><td>Energy Imbalance Management</td><td>A bridge between the continuous regulation service and the hourly/half hourly trading periods. Slower than Continuous Regulation.</td><td>< 10 minutes</td><td>10 min to hours</td><td>10 min to hours</td></tr>
<tr><td>Instantaneous Contingency Reserves (Spinning Reserve and Load Rejection)</td><td rowspan="2">Abnormal operation</td><td>Provided by online resources that can rapidly change output/ consumption in response to a major disturbance (loss of load / generation).</td><td>Seconds to <10 min</td><td>10 min to 2 hrs</td><td>Hours to days</td></tr>
<tr><td>Replacement Reserves</td><td>Provided by resources with a slower response time that can be called upon to replace/ supplement Instantaneous Contingency Reserve.</td><td>< 30 min</td><td>2 hours</td><td>Hours to days</td></tr>
<tr><td colspan="3">Voltage Control (Dispatch Support Services)</td><td>The injection or absorption of reactive power to maintain transmission system voltages within required ranges.</td><td>Seconds</td><td>Seconds</td><td>Continuous</td></tr>
<tr><td colspan="3">Black start (System Restart)</td><td>Generation able to start itself without support from the grid.</td><td>Minutes</td><td>Hours</td><td>Months to years</td></tr>
</table>

Continuous Regulation reserves and Energy Imbalance Management continuously maintain the generation and load balance under normal conditions resulting in system frequency remaining within normal operating requirements. It should be noted that Energy Imbalance Management, although part of the services provided by the System Operator, is not classed as an Ancillary Services in some markets and tends to form part of the wholesale energy market.

Instantaneous Contingency Reserves and Replacement Reserves restore the generation and load balance in the event of a system disturbance or contingency (e.g. the sudden, unexpected loss of a generator or transmission interconnection) maintaining the system frequency within contingency operating limits.

The remaining of this section provides further details of each of the above "essential" Ancillary Services.

4.2.1. Continuous Regulation (*Load Following*)

The Continuous Regulation service matches aggregate generation with aggregate load on an ongoing basis and is essential in maintaining system frequency. The service is primarily provided by a dedicated resource, usually a generator, whose output is adjustable via AGC or equivalent so that the dispatcher can accommodate the minute-to-minute fluctuations of load and generation.

Continuous Regulation is also important in controlling inter-area power flows. If generation exceeds load within one balancing area, then power will flow over the transmission line ties to adjacent areas.

4.2.2. Energy Imbalance Management

Energy Imbalance Management ensures that generation and load is balanced over short time frames so that markets clear and that the physical system is balanced.

Regardless of electricity market design, system operators must always reserve sufficient synchronised capacity to ensure that supply and demand (including system losses) are continuously balanced. In pool markets, there is a need to provide incentives to carry out dispatch instructions that may vary from the day-ahead schedule due to real-time balancing needs. In bilateral markets the system operator must ensure sufficient synchronised capacity is available to balance the market in real time.

4.2.3. Instantaneous Contingency Reserves (ICR)

On occasion, normal system operations are interrupted by unexpected generator outages and/or transmission line failures or other large load disconnections. The system operator must plan for these situations by making sure sufficient coordinated operating synchronised reserves are available that can respond to contingencies while maintaining system frequency and voltage within acceptable limits. The concept and application of Instantaneous Contingency Reserves (ICR) is consistent across electricity markets, although the exact requirements vary (e.g., response time, duration, volume).

In the event of a loss of generation, ICR operates to arrest the initial frequency fall. Conversely, in the event of a large load loss, ICR Operates to arrest the increase in system frequency by reducing generation or adding load. In all cases, ICR is acting to restore the balance between generation and load subsequent to a large system disturbance.

The capacity resources providing ICR are typically much larger and called upon less frequently than those required for Continuous Regulation. The cost of ICR is driven by the provider’s opportunity cost since any capacity held back as an operating reserve cannot participate in the

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energy market. Speed is critical for restoring system stability due to unexpected events, and ICR are therefore distinguished according to how quickly they can respond (increase output) from seconds, to minutes. Reserves that are synchronized to the system (sometimes called "Spinning Reserves") can respond almost immediately and provide frequency support or voltage support for a short duration (minutes to hours). If the generation shortfall persists, then it becomes necessary to replace or supplement ICR with additional operating reserves (i.e. Replacement Reserves).

4.2.4. Replacement Reserve Service

Replacement Reserves have slower response times but are capable of responding over longer durations. They are typically used to supplement or replace Instantaneous Contingency Reserves in restoring frequency and preserving system stability. Replacement Reserves cover a broad spectrum of resources, response times and durations generally up to the market dispatch interval duration.

4.2.5. Voltage Support

The Voltage Support Service is concerned with the management of reactive power, which is essential in controlling voltages across the network. An adequate voltage profile must be maintained throughout the system to avoid voltage collapse, which could result in cascading blackouts.

Typically, in connecting to a system, a generator must provide a standard amount of reactive power or voltage support as part of connection arrangements. Voltage Support as an Ancillary Service refers to reactive power support required beyond the standard level.

The main sources of reactive power are generators and certain transmission plant and devices (such as synchronous condensers, capacitor banks etc). For generators, the excitation system required to provide reactive power is also essential to for the generators to provide energy and is normally a generation connection condition for generators. The main costs for generators in providing reactive power are a marginal increase in losses in the exciter and stator of the alternator and transformer losses, and from increases in maintenance that can be difficult to precisely quantify. These costs are normally quite negligible.

Provision of extra reactive power capability may also require the generator and transformer to be oversized which increases capital costs for the plant. Reactive power cannot be transmitted over large distances and must be provided close to the area requiring voltage support, greatly limiting the scope of potential providers.

As a result of the relatively low inherent cost of providing Reactive Power to generators, and the limited scope for competitive arrangements, Reactive supply is typically not procured through real-time competitive markets.

4.2.6. Black Start

A system operator must have resources available to restart the power system in the event of a blackout. Black Start Services must come from generators that can start on their own auxiliaries and that have enough real and reactive capability and controllability to energise transmission plant and restart additional generators. Loads themselves are not able to supply this service, although loads can be useful in the process of reenergising the interconnected system (NYISO 2004). Loads associated with large generators might have sufficient capability to be useful as black start units. Black Start Services are not addressed in this study.

4.2.7. Other services

Many markets incorporate additional Ancillary Services either by further discriminating some of the types above or by creating new specialised services depending on the characteristics of their generation portfolio and market design. The system operator normally has the responsibility to operate the system in a safe and efficient manner and that includes the capability for identifying new Ancillary Services which may be useful for the system to achieve such objectives.

4.3. Interrelationships between Ancillary Services and the nature of the Energy Market

For generators, the dispatch of Ancillary Services normally results in a restriction on participation in the Energy Market or an out of merit order (inefficient) dispatch. Thus, the dispatch of Ancillary Services directly affects the efficiency of the energy market. In complex Ancillary Services markets the dispatch of energy and continuous Regulation / ICR Ancillary Services are co-optimised in real-time. In simpler markets this real-time co-optimisation may or may not be provided depending on the balancing market. In markets that have no co-optimisation there is necessarily some compromise in economic efficiency.

The times and durations in Table 4.1 reflect the characteristics of the system and the market. Reserve Ancillary Services are the services necessary to (generally) respond and operate at shorter time frames than the market dispatch time interval. For example, in the NEM the generation dispatch time interval for the energy market is 5 minutes. The Frequency Control Ancillary Service (FCAS) are Raise and Lower Regulation, raise and Lower 6 seconds, Raise and Lower 60 seconds and Raise and Lower 5 minutes.

5. Ancillary Services in the SWIS

5.1. Market Structural issues

The SWIS, due to its relatively electrical small size, generation mix, market configuration and the large geographical distances covered, is challenged in terms of Ancillary Services requirements and provision. The relatively small size and island nature of the SWIS means that the generation mix is highly important to the requirement for and procurement of Ancillary Services (confirmed by Study 2c: Impact of Introduction of a Mid Merit Machine with High Spinning Reserve Capability). The islanded nature of the SWIS means that the system is wholly dependent on the generation portfolio within the system, unable to procure support from interconnectors to other large systems as is available in other interconnected markets. The configuration of the existing generation mix, particularly the operating characteristics of individual units when a relatively small number of units are dispatched, has a disproportionately large impact on the requirement for and provision of Ancillary Services. Increasing the volumes of intermittent generation (such as wind generation) in the SWIS is likely to intensify the Ancillary Services dilemma – increasing the requirement for reserve per se and further exacerbating the Ancillary Services issues associated with the configuration of the generation market.

The market structure of the SWIS also represents an Ancillary Services challenge – particularly in terms of provision. The SWIS is dominated by a large incumbent generator, Verve Energy, making the competitive procurement of Ancillary Services challenging, given the size of the dominant incumbent. Furthermore, this market structure of dominance is exacerbated by legacy arrangements and the existing Market Rules, in particular the requirement for Verve Energy to provide balancing services.

The geographical size of the SWIS represents another Ancillary Services challenge – the SWIS extends from Kalbarri in the north, to Albany in the south, and Kalgoorlie in the east of Western Australia. Currently, the Network Control Service proportion of the Market Rules is intended to meet the requirements of this challenge outside the defined Ancillary Services.

It is also important to understand the interaction between Ancillary Services and the Wholesale Electricity Market which is structured around four main revenue streams:

1) A capacity payment through the Reserve Capacity Mechanism (RCM) determined and managed by the IMO. The RCM is intended to ensure sufficient capacity is procured to meet peak summer demand plus an operating margin as indicated in Chapter 4 of the Market Rules.
2) An energy payment through the Bilateral Contracts and the Short Term Energy Market (STEM), a daily forward energy market that allows market participants to trade around their bilateral position arising from a Bilateral Contract Market.

3) Balancing and Ancillary Services managed by System Management with payments handled by the IMO. Currently Verve Energy is the only generator to receive Ancillary Service payments.
4) Balancing Mechanism managed by the IMO. Currently Verve Energy is the only generator to receive balancing payments under normal operation. Non-Verve Energy Participants can be requested to provide balancing services if Verve Energy cannot meet the system requirements in which case these participants get paid a pay-as-bid amount.

Observation 1

Non-Verve Energy generators are currently remunerated for capacity and energy only. There is no existing market signals to drive Non-Verve Energy investment in technology that can improve efficiency in the provision of Ancillary Services.

5.2. Definition of Ancillary Services on the SWIS

In the SWIS, power market Ancillary Services are specified in the Ancillary Services Definitions, Service Standards and Determination and Procurement Requirements, as set out in sections 3.9, 3.10 and 3.11 of the Market Rules. The Ancillary Services defined fit broadly into the categories outlined in section 4.2 and include:

- *Load Following* - adjusting the output of scheduled generators within a Trading Interval so as to match total system generation to total system load in real time in order to correct any SWIS frequency variations. **(Continuous Regulation and Energy Imbalance Management**)
- *Spinning Reserve Service* (**ICR)**, the response of which is measured over three time periods
  - respond within 6 seconds and sustain or exceed for at least 60 seconds; or
  - respond within 60 seconds and sustain or exceed the required response for at least 6 minutes; or
  - respond within 6 minutes and sustain or exceed the required response for at least 15 minutes
- *Load Rejection Reserve Service* **(ICR)**, the provider of which must be able to:
  - respond appropriately within 6 seconds and sustain or exceed the required response for at least 6 minutes; or
  - respond appropriately within 60 seconds and sustain or exceed the required response for at least 60 minutes,
- *System Restart Service* **(Black Start).** Not included in the scope of this study
- *Dispatch Support Service* is any other ancillary service that is needed to maintain power system security and power system reliability that are not covered by the other Ancillary

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Service categories. Dispatch Support Service includes the service of controlling voltage levels **(Voltage Control).**

> **Observation 2**
>
> The time periods for **ICR** services in the WEM (Spinning Reserve and Load Rejection) define a detailed response for time periods less than the half hour trading interval. Although the 15 minute maximum period for Spinning Reserve does not cover the full half hour trading period it does allow for the next fast start machine to be dispatched, possibly out of merit order.

5.3. Determination of Ancillary Service Requirements

5.3.1. Market Rules Determination Guidelines

Clause 3.10 of the Market Rules sets out the levels of Ancillary Services that are to be dispatched, together with the conditions under which variations from these determination guidelines' may occur.

For the Load Following standards dictate that System Management must:

- Provide Minimum Frequency Keeping Capacity, where the Minimum Frequency Keeping Capacity is the greater of:
- 30 MW; and
- the capacity sufficient to cover 99.9% of the short term fluctuations in load and output of Non-Scheduled Generators and uninstructed output fluctuations from Scheduled Generators, measured as the variance of 1 minute average readings around a thirty minute rolling average.

The Market Rules require that the level of Spinning Reserve must be sufficient to cover the greater of:

- 70 % of the total output, including parasitic load, of the generation unit synchronised to the SWIS with the highest total output at that time; and
- the maximum load ramp expected over a period of 15 minutes;

The level of Spinning Reserve must include capacity utilised to meet the Load Following.

Under various operating conditions System Management may vary from the above guidelines for Spinning Reserve:

- The level may be relaxed by up to 12 % by System Management where it expects that the shortfall will be for a period of less than 30 minutes.
- The level may be relaxed following activation of Spinning Reserve and may be relaxed by up to 100 % if all reserves are exhausted and to maintain reserves would require involuntary load shedding. In such situations the levels must be fully restored as soon as practicable

The standard for Load Rejection Reserve Service is a level which is sufficient to keep over-frequency below 51 Hz for all credible Load Rejection Reserve events;

Load Rejection Reserve "may be relaxed by up to 25 % by System Management where it considers that the probability of transmission faults is low.

The Market Rules specify that System Management must detail the quantity of each Ancillary Service needed to meet the Ancillary Service standards over a year for each of the categories of Ancillary Services. In determining the quantity of Ancillary Services required, System Management must take into account a number of factors, including:

- The performance of facilities that may influence the need for additional Ancillary Services; and
- The location specific requirements of Ancillary Services.

The IMO has a duty to forecast generation adequacy over a period of ten years to ensure sufficient Reserve Capacity is procured and certified. In certifying this capacity, the IMO ensures the capacity can deliver a supply of energy at a given reliability and meets the technical rules (through the requirement for an access offer from the Network Operator). Beyond this the IMO makes no assessment of the type of generating technology.

Over the short and medium term System Management plans capacity availability using the short and medium term Projected Assessment of System Adequacy (PASA). The medium term PASA is intended to assess system security and reliability over a rolling 36 month planning horizon while the short term PASA assesses a three week horizon.

The Ancillary Service requirements are subsequently determined by System Management then submitted to the IMO, including the assumptions used to determine the quantity of Ancillary Services outlined.

Observation 3

System Management can only procure Ancillary Services from the generators procured and registered through the IMO (this generation must meet have a connection offer and therefore meet the Technical Rules).

For 2007/08, the Short Term Reserve requirement is 240 MW corresponding to 70 % of the Collie Power Station Generation (340 MW)[3]. Of the 240 MW, 60 MW were calculated as necessary for Load Following. The 180 MW of Spinning Reserve is made up of 52 MW of interruptible loads with the remaining 128 MW provided by generation.

Load Following is currently provided exclusively by Verve Energy generation as established in the Market Rules. Load Following is included in the Spinning Reserve Requirement and, given increasing anticipated volumes of intermittent generation, is forecast to double to 120 MW over the next 3 years[3].

5.3.2. Technical Rules Determination Guidelines

The Transmission and Distribution System Performance and Planning Criteria are indicated in Section 2 of the Technical Rules for the South West Interconnected Network (Technical Rules). In particular, Clause d in 2.2.1 indicates:

> 'The *frequency* operating standards must be satisfied, provided that there is no shortage of Spinning Reserve in accordance with clause 3.10.2 of the Wholesale Electricity Market Rules, without the use of *load shedding* under all credible *power system load* and *generation* patterns and the most severe *credible contingency event.'*

There is also an explicit requirement for the network owner to plan, design and construct the network against a range of credible contingency events which include the sudden disconnection of a generating unit.[4]

Clearly, if the network should be designed to cope with the outage of a generating unit there is an expectation that there would be enough reserve to withstand it without load shedding.

This requirement is a "performance" based requirement which is consistent with the requirements in other markets. It indicates the desired system performance and allows the System Operator to

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[3] System Management Ancillary Services Procurement Strategy" Western Power November 2008.

[4] The *Network Service Provider* must plan, design and construct the *transmission* and distribution systems so that the short term power system stability and dynamic performance criteria specified in clauses 2.2.7 to 2.2.10 are met under the worst credible system *load* and *generation* patterns, and the most critical, for the particular location, of the following *credible contingency events* without exceeding the rating of any *power system* component or, where applicable, the allocated *power transfer* capacity:

(1) a three-phase to earth fault cleared by *disconnection* of the faulted component, with the fastest main *protection scheme* out of service;

(2) a single-phase to earth fault cleared by the *disconnection* of the faulted component, with the fastest main *protection scheme* out of service;

(3) a single-phase to earth fault cleared after unsuccessful high-speed single-phase auto-reclosure onto a persistent fault;

(4) a single-phase to earth *small zone fault* or a single-phase to earth fault followed by a *circuit breaker failure*, in either case cleared by the operation of the fastest available *protection scheme*; or

(5) sudden *disconnection* of a system component, e.g. a *transmission line* or a *generation* unit.

make its own decisions in terms of Spinning Reserve requirements in order to ensure that the desired level of system performance is met reliably, efficiently and economically.

Observation 4

There is a disconnect between the “volume” based Spinning Reserve determination in the Market Rules and the “performance” based determination of the Technical Rules (although they may not be inconsistent). This disconnect does not exist for Load Following or Load Rejection Services

5.4. Price of Ancillary Services

The Market Rules define various processes for the provision of Ancillary Services in the SWIS. System Management undertakes an Ancillary Service Procurement Process aimed at securing sufficient Ancillary Services to meet the levels determined in the Ancillary Service Requirements. However, while provision exists for competitive tendering for Ancillary Services, the main provider of the Ancillary Services; Load Following reserve, Spinning Reserve and Load Rejection Reserve is the Electricity Generation Corporation (EGC) –the generation assets of Verve Energy. This requirement, outlined in Market Rule 3.11.7A, allows for all Ancillary Services, apart from two contracts for Spinning Reserve inherited at liberalisation, to be provided by Verve Energy.

System Management can enter into an Ancillary Service Contract with an alternative supplier if:

- If the EGC lacks adequate resources to provide the required volume of Ancillary Services; or
- If these resources can be obtained at a lower cost from other market participants through a competitive tender.

For Spinning Reserve and Load Following, the availability payment to Verve Energy is based on the MCAP (marginal cost administered price). The payment includes energy and availability payment, with the energy payment at MCAP and the availability a proportion of MCAP set in Market Rule 3.13.3 (currently 15 % for peak periods and 12 % for non-peak periods). Load Following and Spinning Reserve services are paid through the Non-STEM settlement mechanisms and timelines.

At present, it is difficult for third-parties to offer services at a discount to the pricing structure for Verve Energy because energy payments for Ancillary Services are at the participant’s pay-as-bid price, which will be above the MCAP given normal dispatch instructions[5]. In terms of the availability price, to offer Ancillary Services at a lower cost than Verve Energy, a third-party must

[5] This issue is being addressed in Rule Change RC_2008_38 discussed in section 5.7.1

bid at a discount to the existing availability pricing formula. To date Verve Energy has remained as the default Ancillary Service provider and there is limited scope for alternative service providers to flourish.

Observation 5

Under the current Market Rules it may be difficult for other generators to effectively compete with Verve Energy.

There is currently a separate deed with Verve Energy for the provision of Dispatch Support Services. The requirement for these services is determined by System Management and the payments for these services are approved by the Economic Regulation Authority (ERA).

5.5. Dispatch of Ancillary Services

The WEM dispatch process is outlined in section 7 of the Market Rules. The existing dispatch generation in the WEM results in a dispatch priority being as follows:

1. Non-Verve Energy generators dispatched as per their Resource Plan.
2. Verve Energy non-liquid generation dispatched as per the plan agreed between System Management and Verve Energy.
3. Non-Verve Energy non-liquid fuelled generation above Resource Plans dispatched as per IMO merit order. IMO merit order based on participant pay as bid positions.
4. Verve Energy liquid fuels generation dispatched.
5. Non-Verve liquid fuels dispatched as per IMO merit order. IMO merit order based on participant pay as bid positions.
6. Curtailable Loads (including SIL).

De-committing of generation is in the reverse order with IMO instruction based on the turn down pay-as-bid positions.

Through this generation dispatch process, only the reserve capacity available from Verve Energy machines is currently counted towards the Spinning Reserve requirement. The result of this is that 60 % of the generation on the system is being re-dispatched to create the Spinning Reserve required for the entire system.

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As each category of generation (Verve and Non-Verve) has multiple machines with varying generation efficiencies, the disconnects in the dispatch of each category may result in variation from the optimal economic dispatch of both energy and Ancillary Services.

Under the current Market Rules, if System Management were to procure Ancillary Services from Non-Verve Energy generation, these Services would be scheduled a day before and would represent a reduction to a participant's maximum dispatch under a Resource Plan. System Management have advised that Ancillary Services would be dispatched on the basis of least Ancillary Service contract cost. As discussed in section 5.4, Non-Verve Energy generators must provide Spinning Reserve at a cheaper cost than Verve Energy; hence would be dispatched first.

Under this system there is no mechanism for the market or System Management to optimise the total cost of generators dispatched for energy and Ancillary Services. Indeed, under the Market Rules, System Management is provided no market generator cost data on which to make such an assessment.

In the event of a generator being dispatched specifically for Spinning Reserve, the generator will still supply a quantum of energy to the market. The cost of energy from this generator is likely to be much higher than the market cost of energy as this generator would typically be operating at a low capacity factor. For Non-Verve Energy generators, in the current market, this is reflected by the market participant pay-as-bid prices for dispatch above resource plan. In contrast, Verve Energy is paid for this energy at MCAP price. It is noted that the implementation of Rule Change RC_2008_38 (detailed in section 5.7.1) makes an adjustment for the energy purchased from Non-Verve Energy generators when they are providing spinning reserve energy. It does not however adjust the cost of energy provided into the market by a machine dispatched at minimal load for the purpose of spinning reserve. System Management have advised that only those participants whom are dispatched for energy will be able to provide Spinning Reserve, this will ensure Non-Verve Energy providers of Spinning Reserve will provide the service at a cheaper cost as required by the Market Rules.

Observation 6

Under the current arrangements (after the introduction of RC_2008_38) only Non-Verve machines that are dispatched for energy will be able to provide Spinning Reserve.

5.6. Service Standards for the Provision of Ancillary Service

Currently, the service standards set for generators connecting to the SWIS are defined in the Technical Rules. These Technical Rules specify technical parameters consistent with the definition of service standards for Ancillary Services (such as ramp rates etc. in Section 3.3.3). However, the Technical Rules note:

> "The scope of these *Rules* does not include the technical requirements for the provision of Ancillary Services..... *Users* who provide these Ancillary Services may be required to comply with technical requirements over and above those specified in this section 3. These additional requirements will be specified in the relevant Ancillary Services contract."

Currently, System Management makes the determination of the capability of each of Verve Energy's generators to provide Spinning Reserve. For example many coal fired units are limited to 30 MW and cogen plant is limited to 12 MW. This determination is based on previous analysis and experience; System Management does not necessarily have this experience with other generators on the system.

The Power System Operating Procedure: Ancillary Services (PSOP:AS)[6] details the technical requirements for Spinning Reserve, Load Following and System Restart (Black Start) services beyond the requirements of the Technical Rules. It is conceived these standards would be integrated into a standard Draft Ancillary Services contract however; SKM has not been able to identify a copy of any draft contract at this stage.

5.7. Relevant Proposed Changes to Ancillary Services

5.7.1. Rule Change Notice - RC_2008_38: Least Cost Determination of AS

The purpose of Rule Change Notice RC_2008_38 is to allow System Management to procure Spinning Reserve from Non-Verve Energy generators at less than the cost paid to Verve Energy, as required by the Market Rules. The key change of this notice is that Non-Verve Energy generators would be paid MCAP for the balancing energy that is provided during a Spinning Reserve event as opposed to the participants pay-as-bid price.

5.7.2. Monitoring

System Management has developed a model of ideal provision of Spinning Reserve that identifies the ideal expected response for each generating facility. From the ideal generator contingency spinning reserve response model System Management proposes benchmarking existing Verve Energy generator facilities based on the history of actual responses. If for a contingency event, a Verve Energy generator facility response fell below its established benchmark, then rather than applying a penalty, additional Verve Energy generators would be committed to make up for the

[6] System Management Power System Operating Procedure: Ancillary Services dated 2006.

shortfall. This in effect penalises Verve Energy by increasing its operating costs. Once Ancillary Services are acquired competitively from Non-Verve generators then actual responses to contingency events would be measured against the generators contracted response and if under-performance was detected then penalties would be applied.

In addition to the above monitoring regime, twice annual testing of the generating facilities ability to provide the service may also be used as outlined in the Technical Rules. [7]

Observation 7

The proposed monitoring regime has a differential treatment of Verve Energy and Non Verve Energy generators resulting in a differential risk profile for each category of generator.

5.7.3. Proposed Procurement Changes

The Economic Regulation Authority (ERA) has expressed some dissatisfaction with the current procurement strategy for Ancillary Services in particular the progress made by System Management in establish a competitive procurement process for Ancillary Services[8]. System Management dispute this position referring the constraints within the Market Rules highlighted in RC_2008_38. The ERA has also expressed the view that it strongly supports a move to competitive procurement for Ancillary Services, particularly for the relatively high cost component of Spinning Reserve.

5.7.4. Documents under Development

For this study SKM has only reviewed documents published at the time of the review. System Management have advised that documents under development to underpin contracting with Non-Verve Energy generators for Spinning Reserve and Load Following, these documents include the implementation of penalties for non performance.

[7] System Management Ancillary Services Procurement Strategy, Western Power, November 2008
[8] Annual Wholesale Electricity Market Report for the Minister of Energy, Economic Regulation Authority, November 2008

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6. International Ancillary Services Comparison

A number of electricity markets have been chosen to compare Ancillary Services with the Standards and Requirements of the SWIS. The review of international markets and provisions for Ancillary Services is based on the broad definitions discussed above. The review looked at the markets in Australia (NEM), Great Britain, Ireland, New Zealand and Singapore. These markets were selected due to their scale, "island" nature and/or power system reliability.

6.1. Market Descriptions

Table 6.1 summarises peak demand, sales and installed capacity for each of the markets selected for the Ancillary Services comparison.

Table 6.1 Selected markets for Ancillary Services comparison

	SWIS	NEM	BETTA Great Britain	Island of Ireland	New Zealand	Singapore
Peak demand (GW)	3.8	34.4	61	7.0	6.8	5.95
Total electricity sales (TWh)	16	176	350	39	42	41.2
Installed capacity (GW)	3.7	40.7	88	7.8	8.7	12.4

All the markets selected above are larger than the SWIS, although the Single Electricity Market in Ireland and the markets of New Zealand and Singapore are broadly comparable. The market in Singapore stands out in terms of installed capacity relative to its annual peak. The GB market also has a relatively large installed capacity relative to peak demand – this large capacity margin is even more remarkable when considering the relatively small contribution of hydro and wind at the present time.

In New Zealand a relatively large proportion of hydro plant gives the flexibility required for competitive procurement of Ancillary Services. In Singapore the installed capacity is far in excess of the demand. There is a high level of dispatchable generation across a number of participants which supports a good level of competition for the provision of Ancillary Services. Singapore is also geographically compact which significantly reduces reactive power needs.

Each of the above markets have mandatory requirements on large generators to ensure they have the capability to provide the key Ancillary Services of operating reserve and reactive power.

However, in most markets it is accepted that providers of these services incur a cost (direct or opportunity) of provision and as such need to be paid.

6.2. Factors Affecting the Determination and Procurement of Ancillary Services

There are a number of factors to consider when assessing Ancillary Service arrangements across a range of markets. Key factors include:

- Generation mix
- Market configuration
- Geographical size

6.2.1. Generation Mix

The generation mix within any market is crucial to the requirement and procurement options for Ancillary Services. For example:

- The level of hydro – given that hydro is often suited to the provision of some Ancillary Services a large volume of hydro resource will often lessen the cost of Ancillary Services. In New Zealand the volume of hydro has benefited the provision of reserve. This has been illustrated most recently when a sustained lack of hydro inflow has depleted the ability of hydro to provide reserve and therefore additional bilateral contracts for reserve have been required.
- The level of interconnections – generally a high level of interconnection gives additional sources of Ancillary Service. ‘Island’ markets are clearly disadvantaged in this regard.
- The level of intermittent generation – high levels of wind penetration require higher levels of reserve and therefore higher levels of Ancillary Services. If high levels of wind penetration are combined with an island market, then the situation is intensified and the reserve requirement increases further.
- The margin of generation capacity is also relevant whereby a high ratio of dispatchable generation to demand, held by several entities, support competition in the provision of Ancillary Services.

Therefore the generation mix is highly relevant to the total reserve requirement, and so total volume of Ancillary Services required, and the procurement options for Ancillary Services.

6.2.2. Market Configuration

The scale and configuration of the market will influence the complexity of procurement systems. In general larger markets will require (and also may justify) more complex arrangements. The degree of competition in the energy market will also influence the effectiveness of a market based

Ancillary Services system – a market with very few participants will not be as effective as a market with many participants.

6.2.3. Geographical size

Due to the localised nature of some of the Ancillary Services, the distance between load and generation affects the criticality of each ancillary service and subsequently the price that it may be appropriate to pay for its provision. This is intensified in an island system with physically long distances, such as the SWIS.

6.3. Overview of Ancillary Services in selected markets

Using our broad definitions, Table 6.2 shows how Ancillary Services are classified in each of the above market

Table 6.2 Ancillary Services comparison between markets

Market	Continuous regulation	Energy Imbalance management	Instantaneous Contingency Reserve	Replacement Reserve	Voltage Support
SWIS	Load following service	Load following service	Spinning Reserve Load Rejection Reserve	Ready reserve	Dispatch support
NEM	Regulating Raise/Lower services	5 minute (dispatch) spot market	Fast raise service Fast lower service Slow raise service Slow lower service	Delayed raise service Delayed lower service	Network Control Ancillary Service
BETTA	Mandatory frequency response	Balancing mechanism	Fast reserves	Standing reserves	Reactive
Ireland	Automatic generation control	Regulating reserve	Primary reserve Secondary reserve Tertiary 1 reserve Tertiary 2 reserve	Replacement reserve	
New Zealand	Frequency keeping	30 minute spot market	Fast instantaneous reserve Sustained instantaneous reserve		

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Singapore	Regulation	30 minute spot market	Primary reserve Secondary reserve Contingency reserve		

While the definitions of Ancillary Services can be broadly categorised as outlined above, ICR is the principal ancillary service required in all electricity markets in terms of volume and total cost and the primary focus of the analysis in this section in accordance with the scope of the study.

In New Zealand and Singapore ICR is co-optimised with the energy market. In New Zealand this is facilitated by the large amounts of hydro which makes the approach practical given the contribution to ICR offered by hydro (although low hydro inflows has challenged the approach).

While Singapore has followed the co-optimised ICR and energy markets of New Zealand, it is seeing high costs and arrangements are under review. A lack of both flexible plant (e.g. hydro) and interconnection is believed to be the main cause of the high costs in Singapore. Overall the generation mix in Singapore fits less well with the market arrangements than the generation mix in New Zealand. The system is characterised by a high plant margin and the high relative reserve levels are compounded by the relative large size of generation units.

The GB market is the only market designed with complex diverse arrangements – overall it can be concluded that complex arrangements seem to be only appropriate to the large markets. However, while the market in GB is relatively complex, it was recognised that experience of market behaviour and associated system operation issues under the market was required before embarking on the development of Ancillary Services markets.

6.4. Procurement of Ancillary Services

6.4.1. Procurement Arrangements

Table 6.3 outlines current procurement arrangements for each category type in each market chosen

Table 6.3 Ancillary Services Procurement Options

Market	Continuous regulation	Energy Imbalance management	Instantaneous Contingency Reserve	Replacement Reserve
SWIS	Provided by Verve Energy on a regulated basis. If additional balancing required/Verve Energy plant not available, bids from other plant accepted		Spinning Reserve Supplied by bilateral contracts with 2 individual parties on from Verve Energy	Provided by Verve Energy
NEM	Participants make offers for Frequency Control Ancillary Services product on a day ahead basis. The dispatch tool produces co-optimised energy and Ancillary Services bid stack and dispatches resources to meet requirements			
BETTA	Mandatory Competitive tendering and bilateral contracts	SO accepts balancing bids and offers within one hour of real time	Standing reserves contracted through competitive tendering	
Ireland			€/MWh Reserve incentive payment Amount received depends on required and available reserve Rebates for non-provision of service	
New Zealand	Competitive tendering and bilateral contracts	Participants make offers for Ancillary Services on a day ahead basis. SO accepts balancing bids and offers within two hours of real time. The dispatch tool produces co-optimised energy and Ancillary Services bid stack and dispatches resources to meet requirements. Additional requirements can also be bilaterally contracted		
Singapore	Participants make offers for Ancillary Services product on a day ahead basis. The dispatch tool produces co-optimised energy and Ancillary Services bid stack and dispatches resources to meet requirements			

All countries have market arrangements for procuring some or all of their Ancillary Services. The prevalence and effectiveness of Ancillary Services markets strongly reflects the number of potential providers (in terms of generation companies). Where competition is relatively low then bilateral/regulated agreements are more applicable.

Furthermore all markets set such payments on a commercial basis. In terms of allocating the costs of reserve, a mixture of “causer pays” and socialisation of the reserve costs is being used in different markets.

Most of the countries examined have implemented one set of procurement arrangements immediately rather than evolving through a number of stages. The market in Great Britain has evolved since privatisation which has helped with adjustments for changing market structure and behaviour and also with the recognition that the energy market has primacy.

The FCAS market in the NEM started as a term contract procurement method and was subsequently converted to the real-time bid market

Great Britain has a mixture of market arrangements and non-tendered bilateral contracts for the procurement of reserve. This arrangement is intended to give the system operator flexibility in obtaining the necessary types of reserve needed by the system at most economic cost by facilitating market forces where competition is high and controlling information and cost mechanisms where competition is low to minimise cost.

GB, Ireland and New Zealand have started to see an increasing focus on reserve due to the emergence of increasing amounts of wind generation on the network. Increasing wind generation is likely to be a significant issue on managing reserve and procuring necessary services economically in the future.

Due to the small scale of the Irish system, there needs to be a heavy emphasis on the provision of operating reserve. The system operators are aware that, as levels of intermittent generation increase, operating reserve requirements will increase and propose that the provision of operating reserve should continue to be directly incentivised through an individual payment mechanism. This allows the system operators to give clear signals to the market of the demand for operating reserve.

In New Zealand the government has become directly involved in the market to ensure sufficient margin by building its own 155 MW SCGT. In addition further options for procuring reserve by bilateral contract and not through the market directly are also being considered. These measures indicate that the energy/reserve market signals are not driving competition and fulfilling the requirement for reserve as anticipated.

The NZ market is complicated by the interconnector between North and South Islands and the load/generation spread between them creating a large credible contingency for capacity planning purposes (being the loss of the two DC interconnectors).

Even in complex and relatively competitive markets competition issues arise – in Great Britain, when a market was established for frequency regulation, the cost of the service almost doubled.

Observation 8

The review suggests that the SWIS is too small for a full real time competitive Ancillary Services market to be cost effective.

6.4.2. Procured Volumes of Ancillary Services

Table 6.4 shows indicative outline volumes of Ancillary Services in various markets under each broad category type. The volume of ICR in the SWIS is large in proportion to the peak demand of the system; this is a function of the size of the largest machine in comparison to the peak demand of the system.

- **Table 6.4 Regulation and Reserve Volumes**

Market	Peak Demand (GW)	Continuous Regulating Reserves	Energy Imbalance management	Instantaneous Contingency Reserves	Replacement Reserves
SWIS	3.8	60 MW		240 MW (inc. 60MW CRR)	
NEM	31	130 MW Raise 130 MW Lower	Spot	350 MW Fast raise 100 MW Fast lower	350 MW Slow Raise/Lower 400 MW Delayed Raise/Lower
BETTA	61	550-1300 MW (varies by season)	3% of volume	3,250 MW	
Ireland	4.9				
New Zealand	6.8			155 MW	
Singapore	5				

6.4.3. Ancillary Services Procurement costs

Table 6.5 shows recent procurement costs of Ancillary Services in the general categories discussed above. However due to the various categories used internationally and reporting methods used it is not possible to compare all categories on the same basis. Generally Ancillary Services amount for between 1% and 10% of total market turnover. Reserve is the largest component of Ancillary Services.

- **Table 6.5 Comparison of Ancillary Services procurement costs**

Market	Overall Cost of Ancillary Services/MWh	Continuous Regulating Reserves	Energy Imbalance management	Instantaneous Contingency Reserves	Replacement Reserves	Voltage Control
SWIS	A$1	A$1.5m		A$14.3m		
NEM	A$0.6	A$19.9m	Spot	A$119.5m		A$79.8m
BETTA	A$2.05		£13m	£134m		£50m

Ireland	A$2.5					
New Zealand	A$0.8 2007 A$2.9 2008	NZ$0.62		NZ$171.3		NZ$9.5

Observation 9

Ancillary Services costs in the SWIS are currently lower than in comparable sized markets.

6.5. Grid Codes and Market Rules

In all the above markets there are formal Grid Codes that specify minimum performance criteria for the system and connected generators. System Operators generally have an obligation to monitor individual generator performance, including testing to verify performance against the Grid Codes and market rules requirements.

System Operators also have differing powers to enforce compliance against the technical requirements in their respective Grid Codes and Market Rules, ranging from automatic financial incentives to referrals to the Regulatory Authorities for sanction and in, the extreme, licence revocation. However, in most systems licence revocation is unlikely to be applied given the need to maintain capacity and concern that such dramatic regulatory would increase perceived regulatory risk in the market and therefore potentially reduce new entry and competition.

The SWIS technical rules address the majority of the technical generator response requirements of other Grid Codes. In the SWIS, System Management are accountable for the day to day security of the SWIS and ultimately for setting and enforcing incentive penalty regimes (see Section 5.7.2). However, the Network Operator is accountable for the initial testing of generator response performance and other tasks critical to ensuring the security of the system. If there is to be further separation of System Management and the Network Operator, or System Management are to be held to account through a penalty regime for system security, these roles may need to be clarified.

Observation 10

The Technical Rules underpinning generator response performance in the SWIS are consistent with other Grid Codes.

6.6. The Electricity Market in Ireland – a case of particular relevance

Our international comparison of electricity markets concluded that no international market entirely duplicates the unique characteristics of the SWIS and therefore the comparison of the various markets above must be tempered by recognising these unique characteristics. However, one market does display some strong correlations with the SWIS – the electricity market in Ireland, in particular[9]:

- The SWIS is relatively small by international standards, with peak demand of some 3800 MW and installed capacity of around 4500 MW. The market in Ireland has a peak demand of around 4900 MW.
- Compared to most markets the two systems are essentially ‘island’ operations. While there is some interconnection with GB however, the relative size of the interconnection is moderate.
- The electricity market in Ireland has recently become harmonised with that of Northern Ireland and a single competitive Pool has been introduced – as the move begins away from a largely vertically integrated structure – developments with some strong similarities to the SWIS
- The dominant player in each liberalised market remains the state owned incumbent – although competition is increasing
- In each market the penetration of wind is set to increase substantially due to favourable wind conditions, renewable targets and renewable subsidies
- Given the physical similarities between the two markets and given that Ireland embarked on its process of liberalisation sooner and is seeing this process intensified with the creation of a single electricity market between Ireland and Northern Ireland (a UK jurisdiction), then the experience of the Irish market provides some useful insights into some of the issues, including the treatment of Ancillary Services, challenging the SWIS.

6.6.1. Background

In November 2004 a Development Framework for an All Island Energy Market was published, setting out the dates by which a Single Electricity Market (SEM) across the island of Ireland was to be achieved. The SEM high-level design was completed in June 2005 and the Regulatory Authorities set to work on the implementation of a suite of arrangements necessary for SEM Go Live by 1 November 2007. On 1 November 2007 the SEM came into effect with the trading and settlement of wholesale electricity in Ireland and Northern Ireland on an all island basis.

The SEM consists of gross mandatory pool into which all electricity generated or imported onto the island of Ireland must be sold, and from which all wholesale electricity must be purchased. The key design features of the SEM are the pool arrangements where all generators receive and all supplier units pay the same single System Marginal Price (SMP) and a system of collection and distribution of payments for capacity based on fixed amounts determined annually.

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[9] The strong correlation between the two systems was also recognised in a recent Econnect report: South West Interconnected System (SWIS), Maximising the Penetration of Intermittent Generation in the SWIS. Econnect Project No: 1465

At the present time, the structure, treatment and arrangements for the provision of Ancillary Services differ between Northern Ireland and Ireland. As part of a process of moving towards harmonising the treatment of Ancillary Services a number of key issues that are highly pertinent to the situation in the SWIS, in particular:

- The payment structure for Ancillary Services
- The procurement process for Ancillary Services

6.6.2. Reserve

The Ancillary Service of particular relevance is termed 'Operating Reserve' and covers Instantaneous Contingency Reserves and Replacement Reserves as defined in section 4.2. Operating Reserve is part of the Operating Margin which is the amount of reserve (provided by additional generation or demand reduction measures) available above that required to meet expected system demand. The capacity providing operating reserve is required to flexible and controllable to a certain extent and therefore not all generating capacity can fulfil the function of operating reserve.

Due to the relatively small size of the system there is a heavy emphasis on Operating Reserve and, as the penetration of wind generation increases, the requirement for Operating Reserve is also likely to increase. Given the relative importance of Operating Reserve it was decided that the provision of this reserve should be directly incentivised through an individual payment mechanism based on regulatory approved rates.

However, it was also considered that the establishment of a fixed rate approach may not provide sufficient market incentives to promote competition between reserve providers, recognising that the reserve requirements (and associated costs) vary during each day. For example, during the night some plant may remain connected to avoid restart costs and the amount of reserve capacity then may exceed the system requirements without any system operator intervention; however extra reserve generation capacity may be required during the day peak. As a result a reserve remuneration scheme will be introduced based on a fixed minimum regulated rate, but also include a variable proportion that the system operators can adjust depending on system requirements and participants' availability. The variable rates will be subject to regulated caps. The envisaged hybrid fixed/variable rate scheme will allow the system operators to increase or decrease payments based on the provision of reserve from the market participants and the specific short-term system requirements

The initial implementation of the above high level design principles considers only a fixed rate for each type of reserve for simplicity. However the TSO can introduce a variable rate, following approval from the Regulatory Authorities, if it is considered of benefit to the system and its safe and economic operation.

Penalties will also be applicable to participants which, having received a reserve payment, fail to deliver the required level of performance. These regulated penalties will be proportionate with the payments received and will be used to reduce the funding needs of reserve payments, and Ancillary Services in general, from general customers.

6.6.3. Procurement of Reserve

It was decided not to adopt a tendering approach in the procurement of operating reserve. The number of market participants was considered insufficient to ensure competition in the provision of reserve and therefore it was considered that the benefits of tendering might be outweighed by implementation costs. This position was proposed by the Transmission System Operator in its “Vision Document” and endorsed by the Market Authority (regulator).

6.6.4. Grid Code Compliance

In a relatively small power system it is very important for the efficient and economic operation of the system to ensure that the generators maintain the performance required in the Grid Codes as appropriate generator performance helps the system operator minimise costs. Given that the only penalty measure for non-compliance with the Grid Code in Ireland is the extreme licence revocation, it was argued that there were insufficient incentives for generators to maintain Grid Code performance.

The underlying principle for the development of additional performance incentives is that there should be no increase in cost to the electricity consumer. A generator performance incentive scheme of withholding Ancillary Services payments, coupled with a penalty mechanism which will take the form of an amount charged to the unit which is a multiple of the rate paid for performance is to be introduced.

6.6.5. System Operator Incentives

Overall it is considered that the incentivisation of System Operation is desirable as it has the potential to reduce the overall cost to the consumer. The efficiency of the System Operators in determining the required level of reserve and the payment scheme will be evaluated as part of a larger incentivisation scheme.

6.6.6. Summary of Irish Experience

The electricity market in Ireland has some strong similarities with the market in the SWIS and therefore provides some pertinent lessons. A key message is that the size and configuration of the market dictates what might be achievable – a market with a dominant, state owned incumbent generator and supplier is unlikely to provide a robust environment against which to competitively procure Ancillary Services.

Incentivising the *behaviour* of market participants and the System Operator also arises as an important issue. For the market participants incentivising behaviour to comply with the relevant Grid Code requirements through a system of payment penalties and rewards has emerged as more important tool to ensure compliance than the ultimate threat of licence revocation. For the system operator it is now acknowledged that the development of an incentive mechanism is the most appropriate way of actively promoting the most efficient management of the system.

7. Summary of Stakeholder Interviews

As part of undertaking this review key stakeholder were interviewed to record their opinions on:

- What is working in the WEM regarding the provision of Ancillary Services?
- Areas for improvement in the manner in which Ancillary Services are defined determined and procured on the WEM?
- Use of competitive market mechanisms to set prices for Ancillary Services.

Discussions were typically free ranging with many areas outside the scope of this report discussed.

The entities that were interviewed were:

- Babcock and Brown Power
- ERA
- IMO
- Newgen Energy
- System Management
- Verve Energy

A summary of interview responses is provided below:

1) Opportunity must be provided for Non-Verve Energy market participants to provide Ancillary Services.
2) There has been no attempt to procure Ancillary Services from Non-Verve Energy generators.
3) Increasing wind penetration will result in challenges for the procurement of Spinning Reserve
4) Ancillary Services should be provided and procured on a competitive basis.
5) The basis of payments for the current provision of Ancillary Services is not transparent and should be.
6) The provision of Ancillary Services should be an ‘opt in’ arrangement with generators choosing to participate.
7) All Non-Verve Energy generators expressed an interest in providing Spinning Reserve. Verve Energy was happy to see this happen to the extent that any resulting increase in cost did not get passed through to them.
8) The SWIS is a small system and the definition, determination and procurement of Spinning Reserve should be on an administratively simple basis.
9) The lower the regulation in any Ancillary Services markets the better.

10) Real time Ancillary Services markets such as in the NEM would not be appropriate for a market the size of the WEM.
11) Most stakeholders had no issue with the provision of penalties regimes for the suppliers of Ancillary Services. It was however raised that this was tempered with concern over the complexity and significant administrative burden this may introduce. Further, penalties should only be in place to the extent the requirements of the Ancillary Services in question are well defined and funded on a cost reflective basis.
12) Penalties / incentives could be on the basis of changes in the maximum quantum of Spinning Reserve available from a plant, if a generator underperforms the maximum quantum available from that plant is reduced for a period.
13) All generators stated they make operational, contractual and investment decisions based on operation of the market. If a revenue source was available for the provision of Spinning Reserve operational these decisions would be varied in response to this.
14) Investors like set income streams.
15) Any payment for Ancillary Services should be based on the marginal cost above the Reserve Capacity Payment mechanism.
16) Some participants reflected that in the current market design the decisions made by System Management have a large impact on economic efficiency of the system. As such System Management should be motivated by both security and economic performance. System Management current focus appears to be skewed to system security. However, this was countered by the position that System Management is largely restricted from economically optimising dispatch by the current operation of the energy market.
17) Unless there was an ability to respond to events between the settlement of the STEM and real time one major Non-Verve Energy generator indicated that may be reluctant to participate in the provision of Ancillary Services as it is difficult to manage the risk
18) One respondent queried if System Management was the appropriate place to enforce incentive / penalty regimes.
19) The current 70% Spinning Reserve figure is based on experience but has been adjusted from time to time as generation risks on the system change.
20) There has been some recent rule changes around Dispatch Support Services that parties are happy with. However, it was agreed Dispatch Support Services remain the least well defined service.
21) The current application of Resource Plans represent a disincentive for generators other than Verve Energy to support the security of the SWIS.
22) Key participants are keen to see that this study does not stall Ancillary Service Provision changes that are already in process.

23) There is some doubt about the ability of the process in the existing rules to procure adequate volumes of Spinning Reserve.

The interview process was an open ended discussion and as such the discussions often deviated from the scope of this report, a summary of these points raised outside the scope of this study are provided below. As these comments are outside the scope of this report, it is not intended that they be further expanded through the public consultation process.

24) The fact that Verve Energy does not have to meet a Resource Plan skews competition in the market. Verve Energy should be required to submit and dispatch to a Resource Plan.
25) The disconnect between the STEM market deadline (10am) and the gas market (2pm) represents a risk that impacts on participation in the market. Should endeavour to get markets more closely aligned.
26) Verve Energy provide balancing energy that other generators have no opportunity to provide. Balancing (imbalance) energy should be provided on a competitive basis.
27) Portfolio generators wish to be able to respond when one unit varies from resource plan with remainder of portfolio
28) The cost of Verve Energy providing Ancillary Services and Balancing Services exceeds the revenue generated by the provision of this service.

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8. Further Investigation of Key Issues

Issues that have been identified through the reviews detailed in sections 5 and 6 above are further investigated in this section.

8.1. Verve Energy Market Dominance

The role of Verve Energy in the SWIS is that of a dominant player (over 90 % at market liberalisation), and although its market share is expected to reduce significantly in the near future, it still will be over around 60 % by 2010/11. The dominant position of Verve Energy is almost absolute in the Ancillary Services market, created by the Market Rules that state that System Management must procure Ancillary Services from Verve Energy unless Verve Energy cannot meet the Ancillary Service requirements or these services can be provided cheaper than Verve Energy.

The table below shows the aggregate costs for each type of Ancillary Service in 2008[10]. As indicated in the table, the current cost to the market for Verve Energy to provide the Load Rejection Reserve Service and Dispatch Support is zero. Load following and Spinning Reserve are paid via the market at a proportion of MCAP and currently only Verve Energy plant is dispatched to provide these services.

- **Table 8.1 Ancillary Service Payments**

Ancillary Service	Total payment (excluding GST) A$m
Load following	1.49
Spinning Reserve	14.28
Load Rejection Reserve	0
Dispatch support	0
System restart	0.248
Total	16.02

Verve Energy provides Load Following by default as it is not obliged to submit a day ahead resource plan – therefore it is not exposed to imbalance charges on the same basis as other SWIS market participants. The result is that no other generator can provide Load Following from a broad generation portfolio and therefore on the same risk basis as Verve Energy. Further, all Non-Verve Energy generators must provide Load Following at a lower total cost. These constraints represent

[10] System Management Ancillary Services Report, Western Power Ltd, 2008. As published at http://www.imowa.com.au/Attachments/AncillaryServicesReport2008.PDF

material barriers to entry for Non-Verve Energy participants that wish to compete in the provision of Load Following services.

Given that Verve Energy provides Load Following by default it is unlikely that the provision of Ancillary Services in the SWIS is truly cost reflective – with some services provided at apparently no cost, the cost of others capped at the MCAP, that is itself unlikely to be cost reflective (illustrated by the difference between MCAP and pay as bid positions) and others provided by contacts converted from legacy contracts. Ancillary Service provision that is not cost reflective could be considered a barrier to new entry and act against the efficient provision of these services.

The barriers to entry discussed above are driven by the structure of the Market Rules and represent impediments to the market's ability to address Verve Energy's existing market dominance.

There are a number of issues raised by the dominance of Verve Energy in the Ancillary Service market:

- Other potential Ancillary Service providers miss out on the potential revenue stream leading to a potential barrier to the broader energy market entry for new competitors.
- Verve Energy may be providing some services at prices that are not cost reflective – if Verve Energy is providing services below cost then this is potentially discriminatory and also acts as a barrier to entry by preventing alternative more effective providers gaining a potential revenue stream. In effect decreasing the efficiency of the market.

With increasing volumes of intermittent generation on the system, the requirement for Load Following will increase (forecast 120MW within 3 years). If other participants are unable to effectively compete for the provision of this service, the results could vary from a reinforcement of the dominant position of Verve Energy to inadequate quantities of Load Following capacity being available to the market. The ERA has made clear its desire to see the development of a tendered market for Ancillary Services, particularly Spinning Reserve. Furthermore the Market Rules require System Management, when it enters into an Ancillary Services contract, to give consideration to using a competitive tendering process. However given the relatively small size of the SWIS and limited number of participants, the cost of introducing a fully competitive process must be set against the desire of the ERA and requirement of the Market Rules to use competitive tendering.

Observation 11

The treatment of Verve Energy generation in the Market Rules, although logical where Verve Energy was over 90% dominant, may require review as the market share of Verve Energy reduces, particularly as Verve Energy may not be able to provide the required Ancillary Services in the future with increased wind penetration.

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8.2. Ancillary Services and Efficient Dispatch in the SWIS

As described in section 5.5 there is no mechanism in the WEM to economically optimise the efficient dispatch of generation outside the operation of the bilateral energy markets and the STEM (where the most efficient generation would get contracted or cleared earlier and therefore dispatched first).

The operation of the current process for the procurement of Non-Verve Energy Ancillary Services includes no market or technical process to co-optimise the dispatch of energy and Ancillary Services. The decision on which machine to dispatch for Ancillary Services is based on the contract price for the Ancillary Service that is likely to be set in medium term contracts (given the machines is already dispatched for energy). Under this arrangement the market participant has no opportunity to optimise the use of the generating plant on a daily basis; and as previous mentioned System Management do not have the information available to undertake an economic optimisation.

The nature of Spinning Reserve is that plant that is providing this services cannot be used for energy dispatch to the extent of the Spinning Reserve provided. Thus, if the most efficient plant on a system is used to provide Spinning Reserve, less efficient plant must provide generation in its place. The additional cost to the market associated with the less efficient plant providing Ancillary Services is likely to be orders of magnitude higher than any saving in the cost of procuring the Ancillary Service.

For illustration, a 10% saving in the existing annual cost of Ancillary Services would be approximately 1.6 million dollars (refer Table 4.1). This saving is compared to Study 2b: Impact of Market Wide Dispatch of Spinning Reserve, which demonstrates that a change in the dispatch philosophy of ICR results in a saving of $16 million to the total cost of an Optimal Dispatch Market.

Observation 12

The disconnect between the dispatch of Verve Energy generation and Non-Verve Energy generation, and the dispatch of Ancillary Services on least cost for that service, will likely result in movement away from the optimal economic dispatch of generation and therefore be counter the objectives of the market.

In a scenario, under the current rules, where all generators on the system were paid for the provision Ancillary Service, the extent to which a generator could provide that Ancillary Service

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would depend on that generator being dispatched for the provision of energy. In effect, a generator must successfully compete in the energy market before it can provide Ancillary Services.

Observation 13

The ability to provide Ancillary Services would typically depend on a generator successfully competing in the energy market (bilateral and/or STEM).

8.2.1. Generator Performance Incentives

The discussion above has examined some of the roles and responsibilities in the SWIS with respect to reserve management. However, a key aspect is also to ensure that the expected generator performance is actually delivered to the system as expected. With respect to generator unit performance, the Technical Rules in Clause 3.3.3.3 clearly state the expected generating unit response to disturbances in the Power System. The requirements include continuous uninterrupted operation while being subjected to off-nominal frequency and voltage excursions. There are also minimum ramping rate requirements.

It is important to ensure that the existing generators maintain the expected performance. System Management has ample powers to test and verify compliance of generators against the expected and past performance and has developed the processes to do so. However, the current Market Rule arrangements provide no effective operational incentives to maintain performance or similar operational penalties if performance is not delivered. The absence of a system of relatively simple incentives and penalties[11] aimed at enhancing performance delivery introduces an element of risk in the reserve assessments and potentially reduced system reliability caused by the generation fleet.

Conclusion 14

Accountability, transparency, efficiency and system performance could improve significantly over existing arrangements with the implementation of appropriate standards and incentive / penalty regimes.

8.3. Wind generation

The penetration of intermittent wind generation is set to increase in the SWIS and this poses significant issues for the operation of the system and requirements for Ancillary Services.

[11] With the exception of incidents in which Verve Energy acts in a manner that endangers the power system (MR 7.6A.4)

The intermittency of wind generation is a function of variability and predictability. Even if the output of wind generation was entirely predictable, the variability of that output increases the difficulties of matching system supply and demand. Improvements have been made in recent years vis-à-vis forecasting the output from wind farms. In general, over relatively short time frames and with robust historic wind data for a specific site, it is possible to predict wind farm output. Such information can be used by a System Manager, in conjunction with a suitable forecasting error that will increase as the forecast extends, to assist the System Manger in accommodating wind generation onto the system.

However, in addition to predicting wind output is the associated issue of the variability of this output. For a System Manager the issue is planning for and accommodating variability in the output of wind generation within a system in real time given that electricity cannot, economically, be easily stored. An extreme example of wind variability might occur where the output of wind generators declines as peak demand approaches. This fall might then be followed by a rise in wind output at a time when demand is falling steeply. While relatively extreme the example serves to highlight the system management issues associated with wind generation.

There are a number of potential techniques the System Manager might use to accommodate wind variability, and these include:

- Making use of interconnections to neighbouring systems.
- Keeping other generation operating at low output to ‘make good’ any wind variability (reserve).
- Physically restricting the output of wind generation onto the system.
- Limiting the maximum rate at which the output of wind generators can change.

The challenges associated with accommodating wind generation are, for the most part, minimised if the proportion of wind capacity is small relative to the overall size of the interconnected system. The more diverse an electricity system is in terms of hosting differing forms of demand and supply coupled with an interconnected transmission system, the more wind generation may be accommodated within the system. The SWIS is both relatively small and an island system – therefore use of interconnections is not appropriate and the issues associated with large penetrations of wind generation are exacerbated.

While the physical output of wind maybe restricted for the purposes of load following, doing so raises a number of issues, including:

- Since wind has low or nil variable cost, constrained dispatch is generally sub economic.
- It may conflict with renewable/carbon targets.

- It may conflict with any priority network access given to renewable/low carbon technologies.
- Should a wind generator be paid to curtail output?
- Will large and small scale wind farms be subject to the same curtailment criteria?
- Which wind farms should be curtailed?
- Can the wind farms be remotely managed by the System Manager?

Clearly, there are a number of difficult issues that must be addressed when considering curtailing the output of wind generation and, as a result, managing the physical output of intermittent generation as a system operational tool is considered a last resort.

As a result increasing volumes of wind generation will lead to an increasing need for reserve. Indeed System Management estimates that, due to the greater penetration of intermittent wind generation anticipated in the next three years, the current requirement for 60 MW of Load Following in the SWIS is expected to double to 120 MW[12].

The Market Rule requirement to include the generation used to provide the Load Following Service in the determination of the Spinning Reserve requirement is understood to be based on an assessment of a low risk of having a rapid increase in Load Following requirement concurrently with the loss of a major generator. This may be entirely appropriate when much of the Spinning Reserve/Load Following is provided by machines that have spare capacity beyond their ability to provide Spinning Reserve. Take for example a coal fired machine that can only provide 30 MW of Load Following / Spinning Reserve irrespective of loading level. In this case, if there is a requirement for a machine to increase dispatch, to meet the requirements of a declining intermittent generator, there is only a short period (whilst the machine's longer term response mechanisms adjust to meet the new loading level) that the Spinning Reserve would not be available from that machine. Gas turbines on the other hand can typically provide Spinning Reserve / Load Following up to their remaining capacity. Thus if they respond (in Load Following) to a decrease in production of a wind farm the Spinning Reserve on the system the system is exposed having inadequate capacity for a Spinning Reserve event for the time it takes to start another machine (15 minutes). On the SWIS, Spinning Reserve is most commonly provided from gas turbines during peak periods.

Thus, as the penetration of intermittent generation increases, with the resulting increase in requirement for load following; and the use of gas turbines to provide Spinning Reserve increases; the risk of outage associated with a concurrent Load Following and Spinning Reserve event will increase.

[12] System Management Ancillary Services Procurement Strategy" Western Power November 2008.

A Renewable Energy Generation (REG) Working Group has been tasked to explore the impact of intermittent generation in the SWIS and the effects that could have in the existing market arrangements including Ancillary Services. It can be expected that many of the issues indicated above will be covered in the Final Report from the Working Group and hence are not considered any further here.

Observation 15

With increasing penetration of intermittent generation, the use of machines to meet both Load Following and Spinning Reserve requirements may need to be reviewed. It is understood this is within the scope of the REG working group.

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9. Proposed Amendments

9.1. Introduction

The recommended amendments to Market Rules draw from the preceding observations in this report and refer to the results of the two technical studies detailed in Study1 and Study 2.

As the purpose of this report is to provide the basis for the first round of public consultation, SKM has identified a preferred option and alternative options for all proposed amendments.

9.2. Proposed Amendments to Market Rules

9.2.1. Definition: General

The definition of Ancillary Services in the Market Rules is appropriate as it is consistent with standards in other jurisdictions and the energy market structure of the WEM. No changes are required at this time.

Recommendation 1

No change to the Market Rules in the definition of Ancillary Services is recommended at this time.

9.3. Determination

9.3.1. Load Following Quantity

The load following requirement of 30 MW is no longer being used. The requirement to set Load Following to meet 99.9 % of system fluctuations will result in Spinning Reserve capacity being used to meet Load Following requirements 9 hours per year. Whilst common machines are providing Load Following, this period of overlap between Load Following and Spinning Reserve will not result in any technical concerns or economic inefficiencies (within the context of Recommendation 5).

Recommendation 2

No change to the Market Rules in the determination of Load Following is recommended at this time.

9.3.2. Spinning Reserve Quantity

Analysis in Study 1: System Response Model indicates that the level of 70 % may struggle to maintain the system within the required frequency bounds for the loss of the largest machine for loads below 3200MW. In this context, analysis in Study 2a: Impact of Spinning Reserve Volume suggests that the Spinning Reserve target of 70 % of the largest machine is the economically optimal outcome for the Optimised Dispatch version of the WEM. As such the target of 70 % is likely to be the lowest acceptable target for Spinning Reserve on the SWIS, with a slightly higher target of 85 % representing a lower risk of the system deviating outside frequency bounds. The results of Study 1: System Response Model and Study 2: Modelling of Ancillary Service Market mechanisms on Economic Efficiency of the Market demonstrate that when a change is made to the generation portfolio, or generators with high Forced Outage Rates are more heavily dispatched, the volume of Spinning Reserve required to maintain the system within frequency bounds and provide an optimal economic outcome will change.

The requirements for Spinning Reserve in the Market Rules and the performance criteria in the Technical Rules are not necessarily consistent. As generation performance parameters change, the “volume-based” Market Rule determination of Spinning Reserve (70 % of maximum generation or the maximum load ramp over 15 minutes) may not meet the “output-based” performance requirements in the Technical Rules. Indeed, System Management has changed the level of Spinning Reserve during the introduction of new generators etc. in the past (before the introduction of the WEM). Currently System Management can temporarily reduce the targeted volume of Spinning Reserve but cannot increase the targeted volume.

The determination of the economically and technically optimal level of Spinning Reserve is dependent on a range of factors including generator outage rates, level of intermittent generation and the mix of generation in the system. These aspects are not adequately covered by the maximum load ramp rate over 15 minutes criterion.

“Performance” based requirements are common in most deregulated jurisdictions. It empowers the system operator with the responsibility for system performance, largely a technical role, whilst also requiring efficient and economic use of resources.

Recommendation 3

The Market Rules on the determination of Spinning Reserve be revisited to reflect “performance” based criteria as used in the determination of other Ancillary Services in the Market Rules and Technical Rules. Volume based criteria should be developed by System Management through the existing Power System Operating Procedure Process.

Impact on Market Objectives: The results of Study 1b demonstrate that the level of Spinning Reserve required can vary significantly (75MW) under a range of system load and generator conditions. Further, Study 2a and 2b demonstrate that significant market cost efficiency is driven by optimising the volume of Spinning Reserve dispatched ($15 million in Study 1a). Thus, Market Objectives are best met by allowing System Management to respond to changing generation portfolios, without the need for Rule Changes, by defining the performance requirements they must in determining the Spinning Reserve volume requirements.

Alternative Option

- Maintaining the status quo and adjust Spinning Reserve by Rule Changes as required.
- Increase the volume of Spinning Reserve to be procured and widen System Managements capability to deviate from this requirement.

9.3.3. Load Rejection Reserve Service Quantity

The determination of Load Rejection Reserve Services in the Market Rules is currently an "performance" based determination and as such is considered acceptable. System Management have determined that a volume of 120MW meets the performance based requirement. Further, System Management has not identified a need to specifically procure this service at this time.

Recommendation 4

No change to the Market Rules in the determination of Load Rejection Reserve Service is recommended at this time.

9.3.4. Common generators for the supply of Spinning Reserve and Load Following

The increasing penetration of wind generation increases the risk that a Load Following service (caused by a rapid decrease in wind capacity) and a Spinning Reserve service (failure of a major generator) would coincide. This is a future issue that is best addressed by the REG working group.

Recommendation 5

The REG working group should be tasked to consider the use of common machines to supply Load Following and Spinning Reserve services issue in the context of increased wind generation within the WEM.

9.4. Ancillary Services Procurement

There is some inconsistency between the roles of the IMO in ensuring long term generation adequacy and the shorter term generation requirements procured by System Management. The long term planning of the IMO dictates overall volumes of generation required, but is not specific on the type of this generation, a factor which is crucial to System Management when operating the system.

Recommendation 6

Develop the Ancillary Service procurement mechanism to ensure adequate quantities of generation with the required capabilities are available. This would require:

1. Implementation of the technical standard for generators providing Spinning Reserve and Load Rejection Reserve services.
2. Development of a revenue stream for generators meeting this standard and delivering the required service (section 9.5.3).

Impact on Market Objectives:

Analysis in Study 2c concludes that a mid merit generator (modelled on the basis of an LMS100), with the capability to provide large quantities of Spinning Reserve and with high generation efficiencies, have the potential to materially increase the economic and security performance of the WEM.

Alternative Option

An alternative option may be to review the Reserve Capacity Mechanism to take into account generation type. This would require changes to the Capacity Certification Process.

9.4.1. Verve Energy Ancillary Services Market Dominance

All of the qualitative and quantitative analyses undertaken by SKM in this report have concluded that the current dominance of Verve Energy in the Ancillary Services market must be addressed to best meet the objectives of the market. The following recommendations of this section are to implement this.

Recommendation 7

Changes should be made in order to reduce the reinforcement of the dominance of Verve Energy in the provision of Ancillary Services.

Impact on Market Objectives: Analyses in Study 2b demonstrate that the ability to dispatch spinning reserve from all WEM machines has the potential to increase the efficiency of the market by 2 % whilst maintain or improving the security of supply. Study 1b demonstrates that the required spinning reserve can be reduced by up to 20MW by carrying that reserve on a wider range of selected machines. This is function of being able to use a wider range of machines that are more economic and more technically capable for the provision of Spinning Reserve.

Alternative Options

The alternative option is to take no action to reduce the Verve Energy dominance in the provision of Ancillary Services.

9.4.2. Ancillary Services Market Structure

The structure of the procurement of Ancillary Services from the Non-Verve Energy market should be addressed:

- In principle, each service would be procured through a market mechanism.
- The procurement mechanism should promote an adequate supply of the service in an operational timeframe.
- The complexity and cost of implementing the procurement option should be commensurate with the cost of the service and the potential benefits.
- The cost of the service must be practical to calculate and settle.

More complex market-based solutions are best in larger systems (GB), or small systems that are inherently less complex, like NZ, due to specific market conditions (such as significant volumes of hydro generation). The SWIS is a small moderately complex system with multiple coal generators that represent a large proportion of system generation (particularly at minimum loads). Therefore it is likely that at this stage of the WEM the cost of moving towards a fully market based solution will outweigh the advantages (as has been illustrated in Singapore).

Recommendation 8

A real-time market for the procurement of Ancillary Services not be implemented at this time.

Impact on Market Objectives:

Table 6.5 Comparison of Ancillary Services procurement costs demonstrates that markets with more complex procurement mechanisms (BETTA, New Zealand) have higher costs even though these markets have the advantage of scale and hydro electricity generation. From this we can assume that if a complex market based process was implemented in the WEM, a small market with no hydro generation, costs would exceed that of a regulated approach.

Alternative Options

- Implement a real-time market for the provision of Ancillary Services.

9.4.3. Basis of Determining Ancillary Services Prices

Ancillary Services availability prices need to be set at a rate that reflects:

- Average opportunity cost for energy not sold (lost margin) and reduction in operating efficiency.
- Marginal additional cost of providing technology to meet the Ancillary Service requirements above the cost of meeting standard capacity requirements.

Through the above, the rate must be adequate to encourage market participants to provide the Ancillary Service at a volume that meets the determined requirement.

Alternative Options

A number of alternative options may be considered appropriate:

1) Competitive tender process for the provision of Ancillary Services.
2) “Open Book” tender process (where tenders demonstrate cost structures that underpin bid positions) for the provision of Ancillary Services.
3) Regulated Rate setting of the availability prices.
4) The introduction of a regulated rate that can be varied depending on the scarcity of an Ancillary Service.
5) The maintenance of the status quo with availability payment based on a percentage of MCAP.

Depending on the how Ancillary Services are dispatched (refer section 10.1), a common Ancillary Service price for all users may be appropriate. This requirement would shape the nature of the tender process.

The ability for each of these options to set the Ancillary Service availability rate at a suitable price is dependent on:

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- The level of competition within the market;
- The information available to the ERA to determine a regulated position (whether it be a regulated availability price or a regulated % of MCAP); and
- The ability of IMO / System management to effectively scrutinise an open tender process.

SKM believes there is currently limited competition in the market (due to Verve Energy's dominance) and as such believes a purely competitive process may not yield the appropriate outcome. However, for this first draft of this study, SKM will seek feedback from the IMO, ERA, System Management and Market Participants on the best form of price setting. With the information obtained through this process SKM will further refine the recommendation on this issue.

Recommendation 9

No recommendation has been made on the basis for setting the price for Ancillary Services; information received in the first round of public consultation will assist in finalising this recommendation.

9.4.4. The Form of Ancillary Services Procurement Arrangements

SKM believe that the form of agreement for Ancillary Services would be a standard form agreement for those particular services as conceived in the PSOP:AS. This procedure refers to a draft Ancillary Services Contract however SKM has not been able to identify a copy of this document for the Spinning Reserve and Load Following services. As detailed in the PSOP:AS the contract would refer to, or include, the standards outlined in the POSP:AS, penalties, and other commercial terms.

Recommendation 10

The standard form agreement conceived in the PSOP:AS should be developed as soon as possible for the provision of each of the Ancillary Service.

Impact on Market Objectives: This is the cheapest and simplest implementation that SKM can conceive and is consistent with the process outlined in the PSOP:AS.

Alternative Options

- Individually negotiated agreements with each market participant.
- Procurement terms detailed in the Market Rules through a Market Rule Change.

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9.5. Generator Performance Incentives

A key issue is how compliance with the requirements of the Technical Rules and PSOP:AS Standards is achieved, central to this is the behaviour of the market participants and System Management. System Management has sufficient powers under the technical rules to monitor and test generator performance against historic and theoretical performance.

Again, the SWIS bears some close similarities to Ireland – where a system of incentivisation is used and is being further developed for the All Island Single Electricity Market. This includes a system of incentives/penalties on the performance of market participants with particular emphasis on Ancillary Services.

The Performance Standards outlined in section **Error! Reference source not found.** and the Technical Rules would be required as the target for any incentive mechanisms.

As planned by System Management the introduction of a system of incentives and penalties would be most effectively implemented through the Standard Arrangement for Ancillary Services (outlined in section **Error! Reference source not found.**) and could be implemented with limited changes to the Market Rules. Penalties could be directed towards reducing the Ancillary Services funding requirements from customers.

However, to ensure all Ancillary Service providers are competing on the same basis of risk (and therefore the same risk/reward basis), incentive /penalties should be applied on an equivalent basis.

Recommendation 11

Implementation of a penalty regime for failure to provide a declared quantity and standard of Ancillary Service is recommended. This regime should apply on an equal basis to Verve Energy and Non-Verve Energy participants.

Impact on Market Objectives: The events of 28 November 2008 and the analysis in Study 1: System Response Modelling outline the criticality of generators performing as specified to the security of the SWIS.

Alternative Options

The status quo can be maintained.

9.6. System Management Monitoring and Incentives

A move towards “performance based” requirements of Spinning Reserve would imply discretion from System Management as to the amount and type of reserve that is dispatched and contracted. This will place increasing importance on to the ERA's annual review of the effectiveness of the market. Through this review, a financial incentive scheme for System Management could be introduced to encourage efficiencies in the procurement and dispatch of Ancillary Services in the SWIS.

10. Suggested Areas for Further Investigation

This section details areas outside the scope of this study but closely related to optimising the treatment of Ancillary Services in the WEM. As these issues are outside the scope of this study they will not be further developed throughout the consultation phase.

10.1. Dispatch of Ancillary Services

The dispatch of Ancillary Services should be co-optimised with the dispatch of energy within the market. The dispatch of energy and the Spinning Reserve are closely related to the provision of balancing energy within the WEM. As such, the determination of the best option for the current state of the market would require analysis beyond the scope of this report. Four options are outlined below. In all but the last option, a mechanism would be required to allow Non-Verve Energy participants to vary from their Resource Plan when providing Ancillary Services.

1. **Status Quo:** Verve Energy Generation and Non-Verve Energy generation is dispatched separately. Spinning Reserve is dispatched based on contract cost; this dispatch places limitations on participants' activities in the STEM market and the resulting energy dispatch. Verve Energy Generation is then dispatched as per Verve Energy instructions to meet Verve Energy contracted loads, remaining Ancillary Services requirements and balancing requirements.

   Advantages:

   - Provision of Spinning Reserve from Non-Verve Energy machines is committed for the entire Spinning Reserve contract period.

   Disadvantages:

   - The dispatch of Spinning Reserve (low cost impact) determines the dispatch of energy (high cost impact).
   - There is a high risk of market participants of having to provide Spinning Reserve when it is not efficient for them to do so.
   - The disconnect between Verve Energy and Non-Verve Energy dispatch prevents the market's ability to optimisation of the dispatch.

2. **Fixed Price, Opt-in, and Status Quo:** All generators are paid the same availability charge for the supply of Ancillary Services. Non-Verve Energy Generators optimise the provision of Ancillary Service vs. the provision of energy and "offer" Spinning Reserve quantity on a day before basis. This offer would be made before the clearing of the Short Term Energy

Market (STEM); as such participants could use the Spinning Reserve availability payment as a “hedge” against the STEM. Spinning Reserve is dispatched on the basis of the existing energy dispatch merit order. That is spinning reserve would be procured from generators, at the quantity defined by generators, on the basis of the existing dispatch order outlined in section 5.5. Penalties for not making available the declared spinning reserve, or failing to perform when called upon would apply. These penalties would need to be set at a level that drove performance but did not discourage Non-Verve Energy generator participation.

Advantages:

- All participants (excluding Verve Energy) can optimise the dispatch of energy vs. Spinning Reserve from their machines.
- There would be little if no change from existing Market Rules.

Disadvantages:

- A split between Verve Energy and Non-Verve Energy generation dispatch still results in suboptimal dispatch.

3. **All generators are treated as Non-Verve Energy Generators:** In this case Verve Energy are required to submit resource plans as per existing market processes. Participants nominate, as part of the STEM process, the level of Spinning Reserve they wish to provide. Particular participants have agreements in place to provide Load Following services through AGC. Generation is dispatched as per the existing resource plan followed by merit order process without separate dispatch of Verve Energy (Verve Energy is dispatched on resource plan and merit order). Flexibility is provided around resource plans to the extent Ancillary Services are being provided (Load Following, Spinning Reserve and Load Rejection Reserve Services).

Advantages

- Removes the Market Rules reinforcement of Verve Energy’s dominant market position.
- Allows the energy market to drive towards economically optimal dispatch.
- Uses processes and systems that exist within the WEM.

Disadvantages

- May increase administrative burden on System Management as acceptable movements from resource plan will need to be recorded and reflected in the balancing market settlement (although this occurs currently).

4. **Introduction of competitive Balancing Market:** This option is the introduction of a full competitive balancing market for the WEM where energy and Ancillary Services dispatch is optimised within a dispatch engine.

   Advantages

   - This option ensures optimal dispatch of generation through open and transparent competition.

   Disadvantages

   - This would require a major overhaul of the existing Market Rules and the development of new processes and systems. This would be a costly and time consuming process.

10.2. Payment for the Impact of Wind Generation on Ancillary Services

With increasing the volume of wind generation there is an increased requirement for substantial Ancillary Services. The distribution of the associated costs needs to be decided upon. Use of a 'causer pays' system could conflict with renewable targets and the priority given to renewable generation sources. These issues are being addressed in another study by the REG Working Group.

10.3. Black Start

The service of Black Start generation was specifically excluded from this study. SKM understand the current procurement processes is a competitive procurement process. Black Start is a relatively straight forward service that does not interact with the day to day operation of the energy or capacity markets and as such the current procurement process appears appropriate.

11. Summary

This study of the treatment of Ancillary Services in the WEM has reviewed the definition, determination and procurement of Ancillary Services. This review identified the following issues:

- System Management currently procures Ancillary Services from capacity that is procured by the IMO. Through this process there is no mechanism to drive the type of capacity that may best meet the Ancillary Services requirements of the market.
- The time period for the **ICR** services on the SWIS (Spinning Reserve and Load Rejection) have the capability to define a detailed response for time periods less than the half hour trading interval of the WEM. Although the 15 minute maximum period for Spinning Reserve does not cover the full half hour trading period it does allow for the next fast start machine to be dispatched.
- There is a disconnect between the “volume” based Ancillary Service determination in the Market Rules and the “performance” based determination of the Technical Rules.
- Under the current procurement processes it may be difficult for other generators to effectively compete with Verve Energy.
- Under the current arrangements (after the introduction of RC_2008_38) only Non-Verve machines that are dispatched for energy will be able to provide Spinning Reserve.
- The proposed monitoring regime has a differential treatment of Verve Energy and Non Verve Energy generators resulting in a differential risk profile for each class of generator.

The study also contrasted the treatment of Ancillary Services in the SWIS against those in relevant international energy markets, in particular Ireland. This contrast resulted in the following observations:

- The SWIS is too small and not sufficiently competitive for a full Ancillary Services market approach to be cost effective.
- Ancillary Services costs in the SWIS are currently lower than in comparable sized markets.
- The Technical Rules underpinning generator response performance in the SWIS are consistent with other Grid Codes.
- A summary of key stakeholder feedback from interviews was provided. Here the key issues appeared to be a requirement from all participants for Non-Verve Energy generators to be able to participate in the Ancillary Services market and an identification of the role the balancing market has in the treatment of Ancillary Services in the WEM.

Information from the reviews and the stakeholder feedback was used to highlight key issues, as summarised below:

- The preferential treatment of Verve Energy generation in the Market Rules, although logical where Verve Energy was over 90 % dominant, may require review as the market share of Verve Energy reduces. This will become of increasing importance if Verve Energy is not able to provide the required Ancillary Services in the future when there is significantly increased wind generation.
- The disconnect between the dispatch of Verve Energy generation and Non-Verve Energy generation, and the dispatch of Ancillary Services on least cost for that service, will likely result in movement away from the optimal economic dispatch of generation and therefore be counter the objectives of the market.
- The ability of a generator to provide Ancillary Services would typically depend on a generator successfully competing in the energy market.
- Accountability, transparency, efficiency and system performance could improve significantly over existing arrangements with the implementation of appropriate standards and incentive / penalty regimes.
- With increasing penetration of intermittent generation, the use of machines to meet both Load Following and Spinning Reserve requirements may need to be reviewed. It is understood this is within the scope of the REG working group.

These conclusions have driven a set of recommendations. The benefits generated by these recommendations have been quantified through two studies: the first examining the frequency response of the SWIS in the event of the loss of the Collie Power Station, for a range of Spinning Reserve treatments. The second providing an economic model of the WEM based on an Optimised Dispatch Market using Monte Carlo analysis to provide an indication of unserved energy.

The resulting recommendations and key benefits are as follows:

1) No change to the Market Rules regarding the definition of Ancillary Services is recommended at this time. *Existing definitions effectively cover all Ancillary Services for the WEM as it exists today.*
2) No change to the Market Rules in the determination of Load Following is recommended at this time. *The existing determination criteria can adequately respond to changes in the market.*
3) The Market Rules on the determination of Spinning Reserve be revisited to reflect "performance based" criteria as in the determination of other Ancillary Services and the Technical Rules. *Although the current determination is the economically optimal and lowest technically acceptable volume of spinning reserve, this change will allow the determination of Spinning Reserve to be optimised as generation parameters on the WEM change.*
4) No change to the Market Rules in the determination of Load Rejection Reserve Services is recommended at this time. *The existing determination criteria can adequately respond to changes in the market.*

5) The Renewable Energy Generation (REG) working group review the use of common machines to supply Load Following and Spinning Reserve services in the context of increased wind generation within the WEM. *With the increase in wind generation penetration on the SWIS, the risk of a concurrent Load Following and Spinning Reserve event will increase.*
6) Develop the Ancillary Service procurement mechanism to ensure adequate quantities of generation with the required capabilities are available. *Studies demonstrate that the introduction of a (higher efficiency simple cycle gas turbines eg LMS100) would decrease the cost of the Optimised Dispatch Market by over $30 million per annum and increase the security of supply. At the moment there are limited market mechanisms to support Non-Verve Energy Generators to develop these technologies.*
7) Changes should be made in order to reduce the reinforcement of the dominance of Verve Energy in the provision of Ancillary Services. *Studies demonstrate that procuring Spinning Reserve and Load Following from all existing market participants (at the same price as is paid to Verve Energy) will decrease the cost of the Optimised Dispatch Market by $16 million per annum whilst improving system security. This would be achieved with no additional capital investment.*
8) A real time market for the procurement of Ancillary Services is not implemented at this time. *Evidence concludes that a full real-time market for Ancillary Services in the SWIS would result in a suboptimal outcome.*
9) No recommendation has been made on the basis for setting the price for Ancillary Services (however alternatives have been provided); information received in the first round of public consultation will inform this recommendation. *Further stakeholder feedback is sought.*
10) A Standard Form Agreement for the provision of each of the Ancillary Services should be developed as soon as possible. *SKMs current view is that this likely to be the most cost effective solution.*
11) Implementation of a penalty regime for failure to provide a declared Ancillary Service is recommended. *Based on results of international comparisons.*

In addition to the recommendations above, SKM has outlined areas that may require further investigation to further optimise the treatment of Ancillary Services in the WEM. These areas are the dispatch of Ancillary Services and the payment for the impact of wind generation on Ancillary Services. SKM has also provided a general comment on the treatment of Black Start generation within the WEM.

12. Next Steps

This report is the first draft to be issued for the first round of public consultation. The timetable for the public consultation process is as follows:

- 1st Round Public Consultations: **20 April – 18 May**
- SKM to deliver Second Draft Report : **12 June**
- 2nd Round Public Consultations : **19 June – 7 July**
- SKM to amend Final Report : **3 August**
- Publish Final Report: **21 August**

13. Study 1: System Response Modelling

13.1. Study 1a: Load Relief

The level of Spinning Reserve is typically determined to cover the contingency of the largest machine on the system. This contingency can be met by increasing generation (governor response of spinning reserve machines) or by decreasing load. By determining a level of Spinning Reserve below the full capacity of the largest machine, a System Operator is depending on a decrease in system load in the event of the loss of that machine. This decrease in load can come from three sources:

1. System Load Relief: In the event of a loss of generation, system frequency will drop, and associated with this decrease in frequency is a decrease in load. Load Relief is an inherent response of load to a reduction in frequency and does not result in a loss of supply to customers.

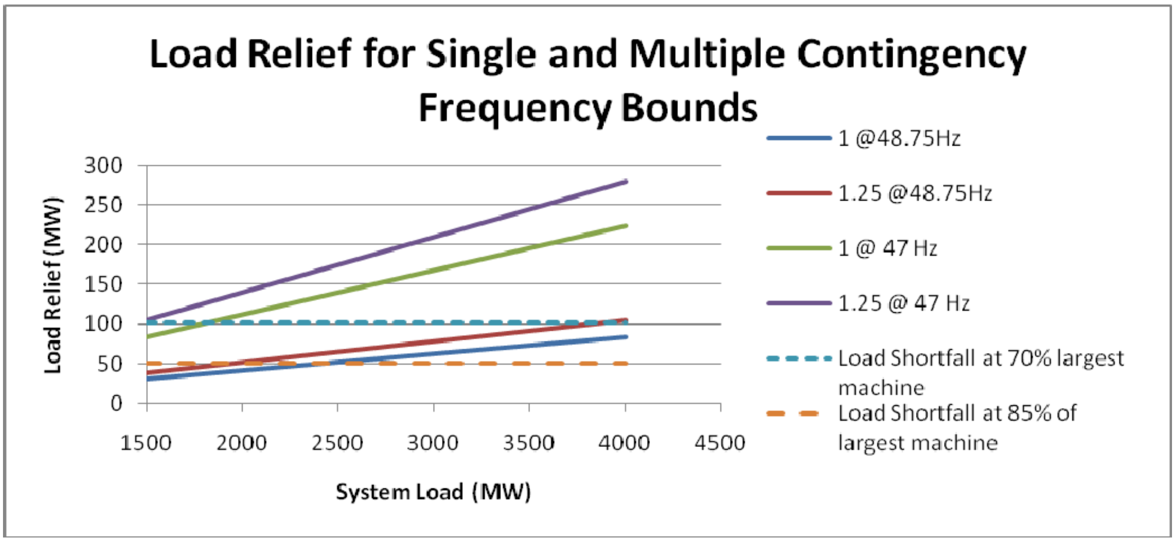
2. Voluntary Load Tripping: Load can be arranged in advance to trip off in a contingency event, the SIL load on the SWIS is an example of this.

3. Forced Load Tripping: If the frequency falls too low, the UFLS system will be forced to turn off a section of customers to maintain the integrity of the system. This load loss results in unserved energy.

Typically, Forced Load Tripping is not used in the planning for a single event outage such as the loss of 1 generator. On the SWIS, SIL is currently used as a component of the 70 % Spinning Reserve target and as such does not contribute to meeting the 30 % shortfall. Thus, the only load reduction available to manage the 30 % shortfall in generation that does not result in unserved energy is Load Relief.

In the case of the SWIS, for the largest machine to trip without the loss of load, the Load Relief must be greater than the difference between the Spinning Reserve and the capacity of the largest machine. At the 70 % Spinning Reserve target, load relief must be greater than 102 MW to avoid loss of load. Figure 13.1: Load Relief demonstrates the expected load relief on the system for various load levels at the Single Contingency lower frequency limit of 48.75 Hz[13] and the multiple contingency frequency limited to 47.0 Hz.

- **Figure 13.1: Load Relief**



Load Relief is expressed as a factor representing the percentage decrease in load for every percentage decrease in frequency. No data on the load relief on the SWIS was provided for this study and as such Figure 13.1 is based on SKM's expectation for Load Relief on systems such as the SWIS of between 1 and 1.25.

The Load Relief in Figure 13.1 is calculated for a reduction in frequency from 49.8 Hz, the lower bound for the normal operation of the SWIS.

Clearly, the load relief available at the single contingency frequency deviation bound (48.75 Hz) is not sufficient to meet the shortfall in generation for a loss of the Collie generator with a 70% Spinning Reserve target. Subsequently, the frequency will deviate outside the single contingency bounds before the Load Relief increases to the shortfall in generation.

The system will, however, have had adequate load relief by the time system frequency reaches the multiple contingency limits of 47 Hz. However by this stage the UFLS system will be in operation and load will be shed[14].

At a Spinning Reserve target of 85 % load relief is adequate for almost all load conditions.

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[13] Technical Rules Table 2.1
[14] Technical Rules Table 2.8

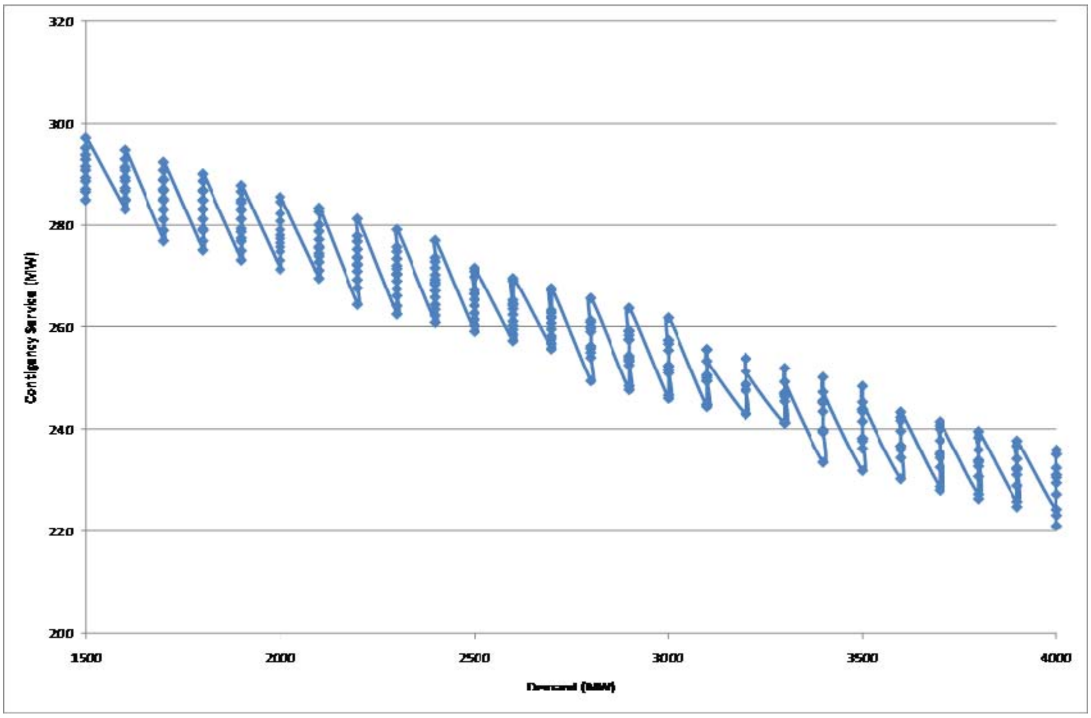
SKM

Observation 16

In the event of the loss of Collie Power Station at full production, the 102 MW load shortfall (70 % Spinning Reserve determination) cannot be met by system Load Relief. At 85 % Spinning Reserve determination would be required for load relief to meet generation shortfall at most loads.

13.2. Study 1b: Modelling Of Determination and Procurement Requirements on System Stability And Security

▪ **Figure 13.2: Spinning Reserve Required to Maintain 48.75Hz for varied Generation Portfolios**



As outlined in study 1a less system load relief is available at lower loads, this results in a larger requirement of Spinning Reserve (Contingency Service) to maintain the system within the frequency bounds at this loads.

Observation 17

Based on the data used in SKMs modelling, the Spinning Reserve volume of 70%, or 243MW, only maintains the system within the required frequency bounds for a proportion of system loads.

The vertical variability represents a range of generator dispatches that will maintain system frequency deviation within 48.75 Hz for the given system load. The graph demonstrates that the level of reserve required can vary by 18MW, or approximately 7%, depending on the nature of the generators providing response at that time. This is a function of the speed at which the given portfolio of generators can respond to arrest the frequency fall in the contingency events.

Observation 18

The capability of machines providing the Spinning Reserve service can result in a material variation in the volume of spinning reserve required to maintain system frequency.

13.3. Approach to Modelling

The frequency response of a transmission system to a disturbance caused by the loss of connected generation or load depends primarily on the inertial response of the system, load damping and the action of governors subjected to frequency errors. However, each of these elements is in turn dependent upon a large number of other factors and higher order responses. A detailed and and complete analysis of the frequency behaviour of a system requires complex and time-consuming modelling of each element of the system. This more detailed approach is appropriate for considering a small set of system operating conditions but does not lend itself to the broad scan of conditions required by this report.

The intention of this study is to determine the average response of the SWIS for given sets of conditions and to assess the variability of the response to changes in parameters such as the mix of generation (Gas Turbines versus Steam Reheat Turbines) and the number of generators with active governors participating in the containment of frequency following a system disturbance. SKM's approach, which is well documented in the literature[15,16], has been to develop the lowest order model of system frequency which accurately represents average system frequency behaviour while taking account of typical turbine and governor time constants and gains. Other system dynamics such as inter-machine oscillations and transient, non-linear or discontinuous behaviour of loads are not considered.

Fundamentally, the model to be used represents the Laws of Motion which state that any unbalance in forces result in acceleration. In this case, an unbalance between the mechanical torque provided

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[15] Igor Kuzle, Tomislav Tomisa and Sejid Tesnjak, "A Mathematical Model for Studying Power System Frequency Changes", *IEEE Africon 2004*, p761-764

[16] P Kundur, *Powewr System Stability and Control*, Mcgraw-hill 1994, Ch 11.1

by the turbines and the electrical torque required by the loads results in an accelerating torque which causes the speed to deviate:

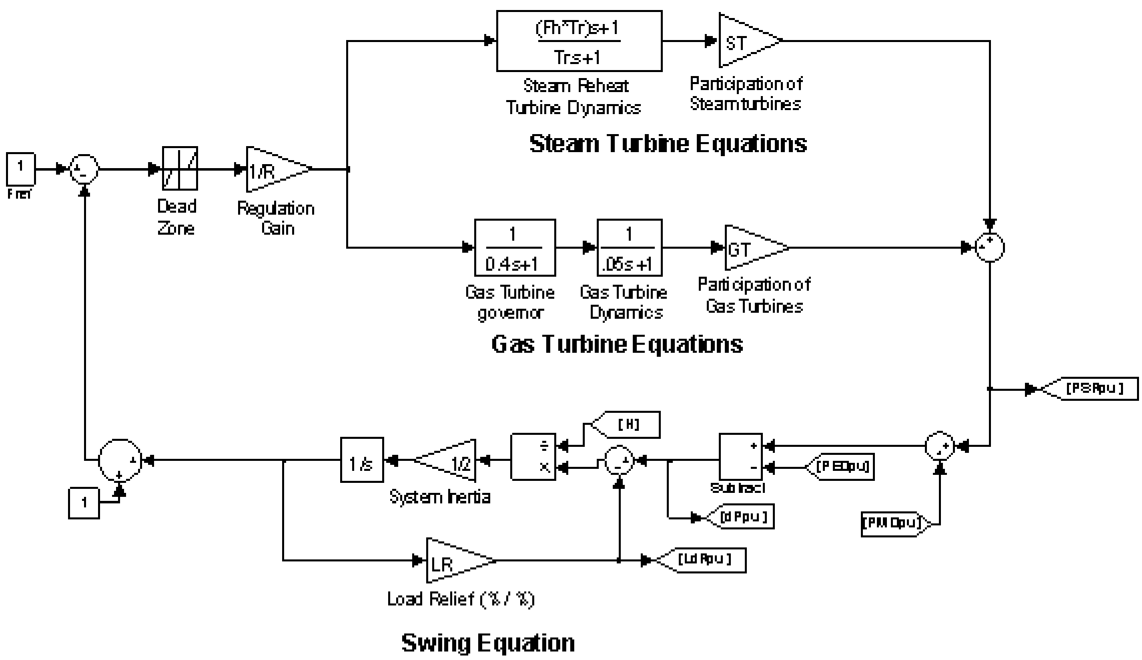
$$T_a = T_m - T_e$$

Power is given by torque times rotational speed and for small deviations of torque where the system was initially in equilibrium, it is possible to demonstrate that :

$$\Delta P_m - \Delta P_e = \Delta T_m - \Delta T_e$$

Using these principles combined with Newtons Laws of Motion, a low order system model can be developed which aggregates the response of individual machines into single machines representing Gas and Steam turbines and represents load damping at the aggregate level rather than at the individual load level.

SKM has used Matlab Simulink to develop the following low order model of system frequency.



A screenshot of the complete model, including calculations based on input signals is given in Appendix A.

Based on detailed model data provided by Western Power and SKMs experience and knowledge of power systems, the following parameters were used in the simulation

Table 13.1 Study 2 Modelling Variables

Term	Description	Value
LR	Load relief due to frequency dependency of load	1 % load reduction per 1% frequency variation
H	System inertia constant	5.1 MW s /MVA
R	Governor droop	5%
Fh	Percentage of steam turbine power emanating from HP shaft	30%
Tr	Steam turbine reheat time constant	10 seconds

The contingency under consideration is the loss of Collie Power Station with an output of 343 MW and a rating of 412 MVA. Simulations were undertaken to determine the maximum frequency deviation and the total increase in generator output at that frequency. System demand was progressively increased from 1500 MW to 4000 MW to represent the full range of system conditions. The number of generators of each type which are contributing to frequency containment is determined by increasing the aggregate MVA rating of that type of machine from 0 to 1000 MVA. The participation factors for each of the two types of turbines (GT and ST) correspond to the portion of the frequency deviation which is seen by each machine under consideration. The result of this study process is a wide sweep of scenarios across all conceivable system loads and mix of steam and gas turbine generation. From this sweep, the scenarios that result in a variation of system frequency to 48.75 Hz have been extracted and presented in Figure 13.2.

SKM

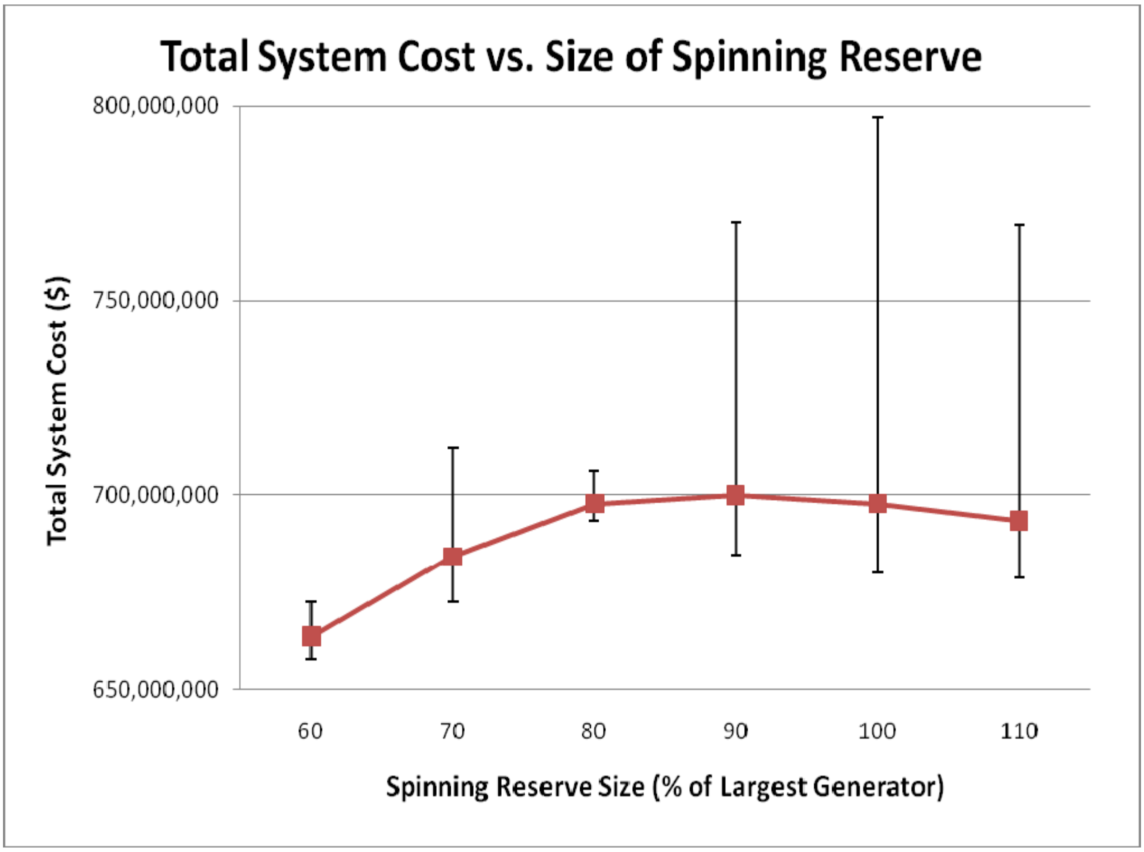
14. Study 2: Modelling of Ancillary Service Market mechanisms on Economic Efficiency of the Market

14.1. Summary of Results

The results in this section are provided in graph format with the average outcome of the Monte Carlo simulations shown as a solid line and the full range of the outcomes demonstrated through bars of variation. For example, in Figure 14.1the average outcome for the 70 % reserve target was $683 million with the Monte Carlo outputs varying from $675 million to $715 million.

14.1.1. Study 2a: Impact of Spinning Reserve Volume

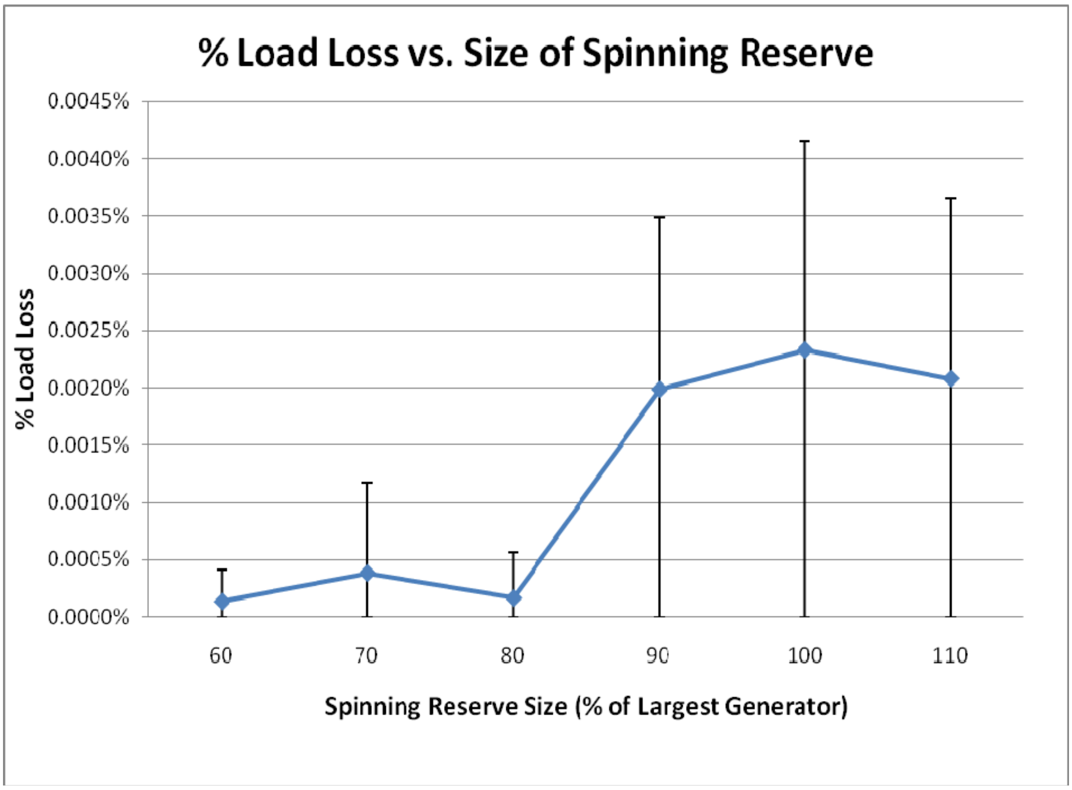
- **Figure 14.1: Total Optimised Dispatch Market Cost vs Spinning Reserve Level**



With the Verve Energy only dispatch of Spinning Reserve in the Optimised Dispatch Market, the study demonstrates that the lower the amount of Spinning Reserve that is carried, the more cost effective the outcome to the market. This holds true until 90 % Spinning Reserve is reached, where the reduction in generation starts to reduce the total generation cost. The delta between the 70 % dispatch target and the worst case at 90 % is 15 million dollars.

The increase in the breadth of outcomes for the higher Spinning Reserve dispatch targets appears to be the result of the increased dispatch of machines with high Forced Outage Rates (Worley Cogen and Muja G5)

- **Figure 14.2: Unserved Energy vs Spinning Reserve Level**



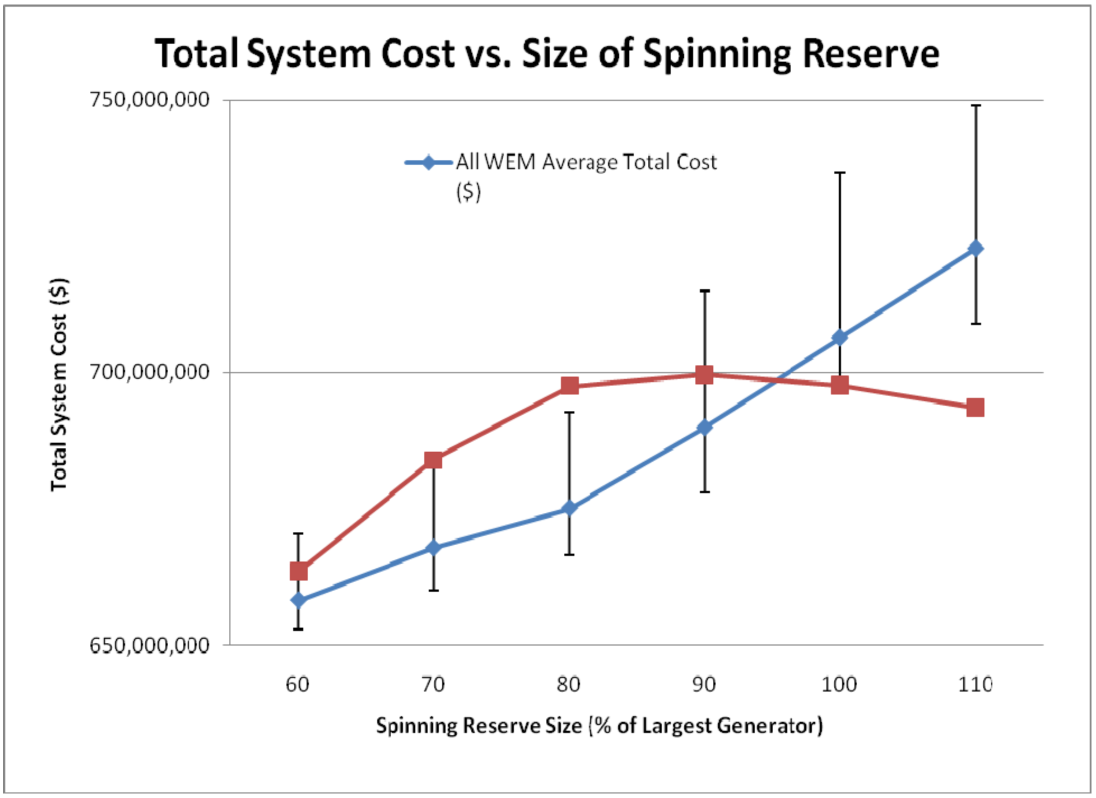
At the current Spinning Resreve target of 70 %, the average unserved energy is within the bounds of the 0.002 % nominated in the rules for the planning of Reserve Capacity. The increase range in the Monte Carlo outcomes for the higher Spinning Reserve targets is again due to the increase in the dispatch of plant with high forced outage rates.

Observation 19

With the generator data provided combined with the assumptions made on fuel cost, the optimal level of dispatch for the Optimal Dispatch Market would be at 70 % of the Collie Power Station.

14.1.2. Study 2b: Impact of Market Wide Dispatch of Spinning Reserve

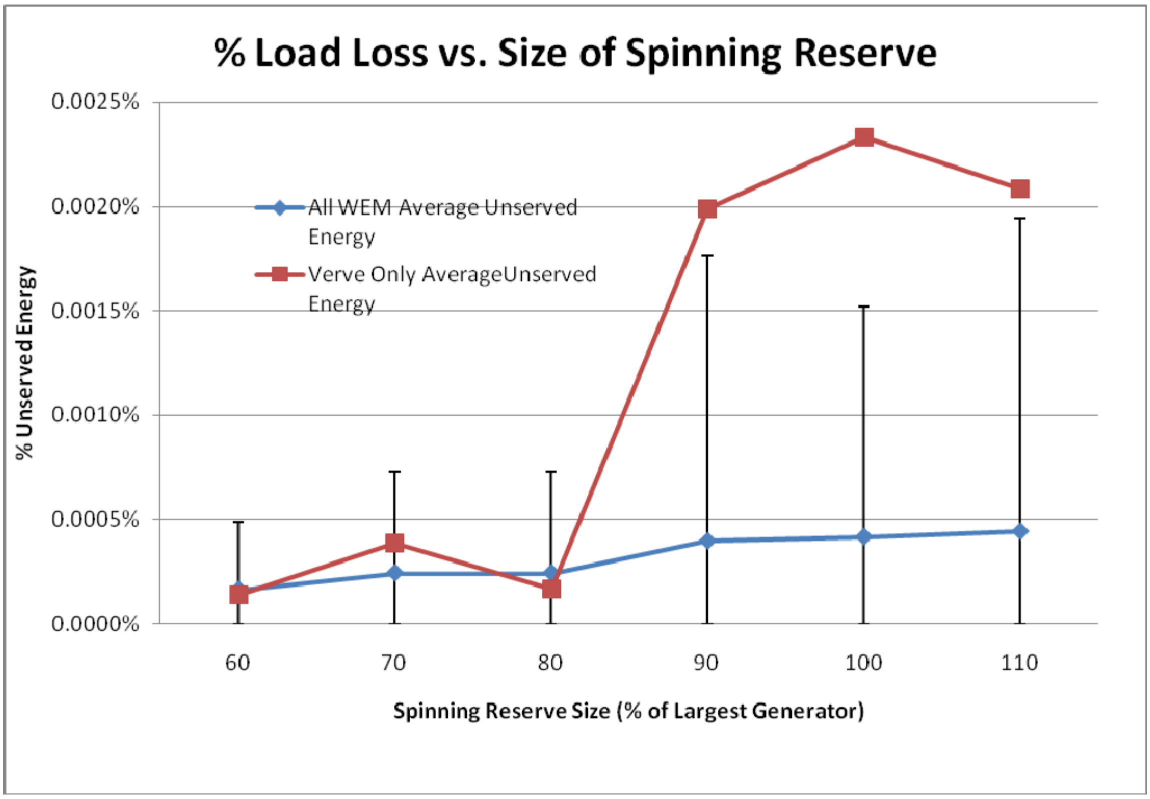
- **Figure 14.3: Economic Cost of Verve Energy Only Dispatch vs Market Dispatch**



The WEM market dispatch provides superior economic outcomes at almost all realistic targets (less than100 % Spinning Reserve). At the 70 % target the Optimised Dispatch Market is $16 million, or 2 % cheaper than the variable costs of the market. This is without any additional investment in generation or change in the price paid for Spinning Reserve (assuming Spinning Reserve can be procured at the existing cost).

SKM

- **Figure 14.4: Unserved Energy vs Spinning Reserve Level**



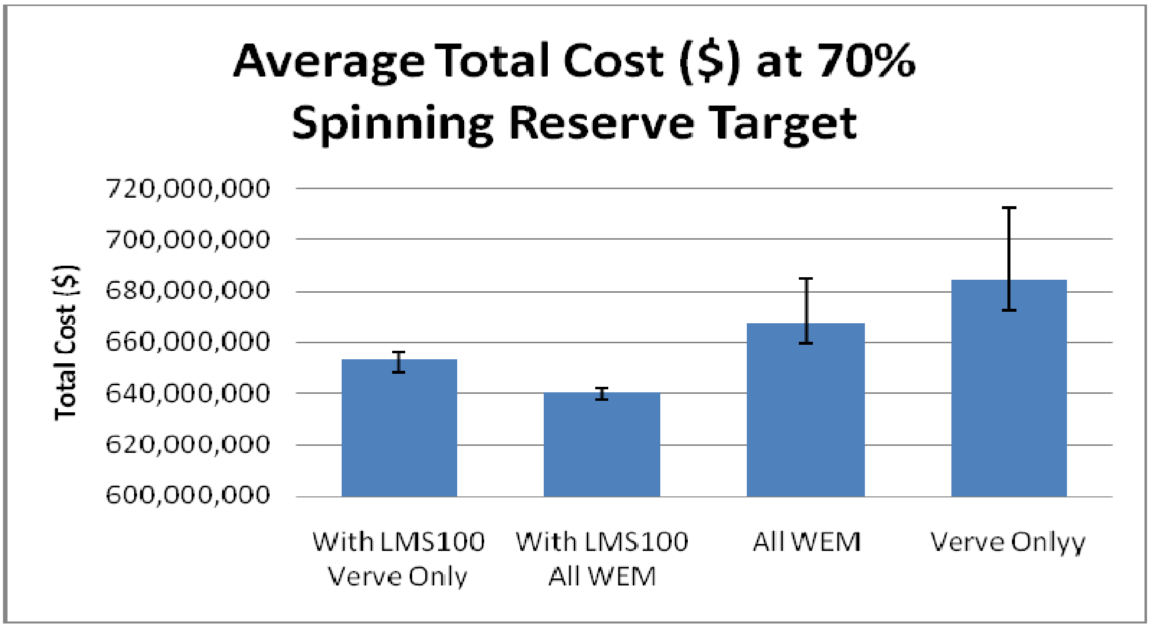
The average unserved energy is lower for all except 80% of the Spinning Reserve targets.

Observation 20

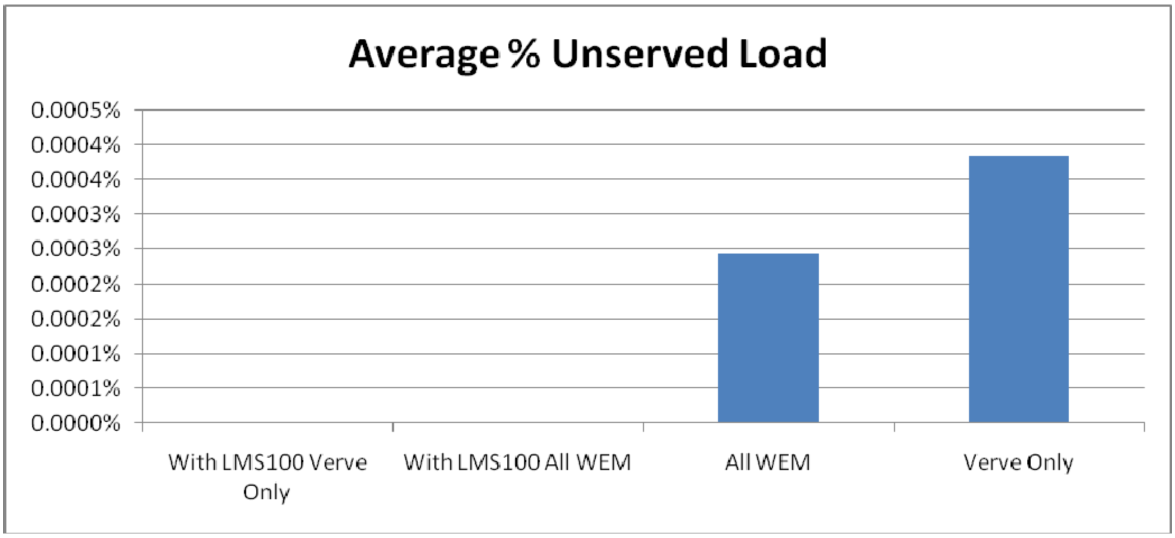
The ability to dispatch Spinning Reserve from all WEM machines has the potential to increase the efficiency of the market by 2 % whilst maintain or improving the security of supply.

14.1.3. Study 2c: Impact of Introduction of a Mid Merit Machine

- **Figure 14.5: Total Impact on Total Average Cost of the Introduction of LMS100 to the WEM**



- **Figure 14.6: Impact on Average Unserved Load of the Introduction of LMS100 to the WEM**



The introduction of a classic mid merit machine to the WEM, effectively displacing one of the less effecient OCGTs on the SWIS, results in a $31 million or 4.5 % decrease in the total variable cost of the Optimised Dispatch Market. Further, the average percentage unserved load approaches zero.

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Observation 21

Mid merit generation technologies, with the capability to provide large quantities of Spinning Reserve and high generation efficiencies have the potential to materially increase the economic and security performance of the WEM.

14.1.4. Study 2c: Fuel Cost Sensitivity

- **Table 2 Sensitivity Analysis: Total Optimised Dispatch Market Cost vs Spinning Reserve Level**

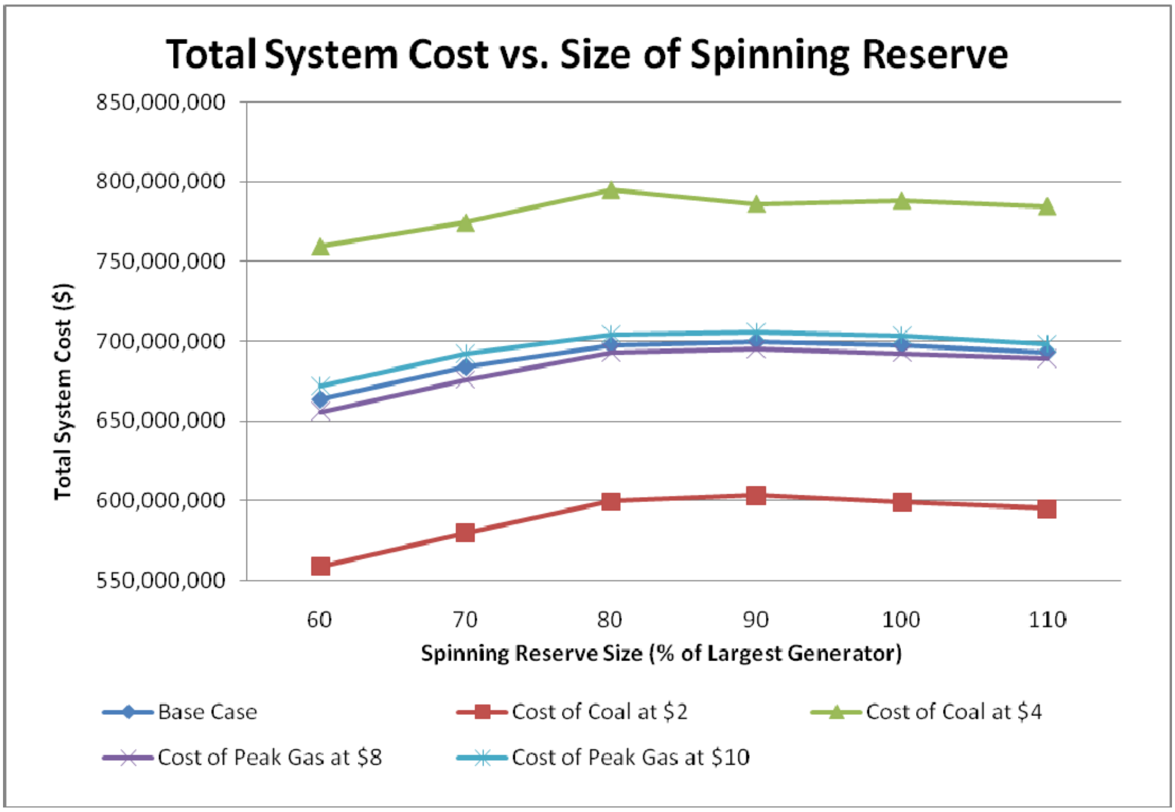
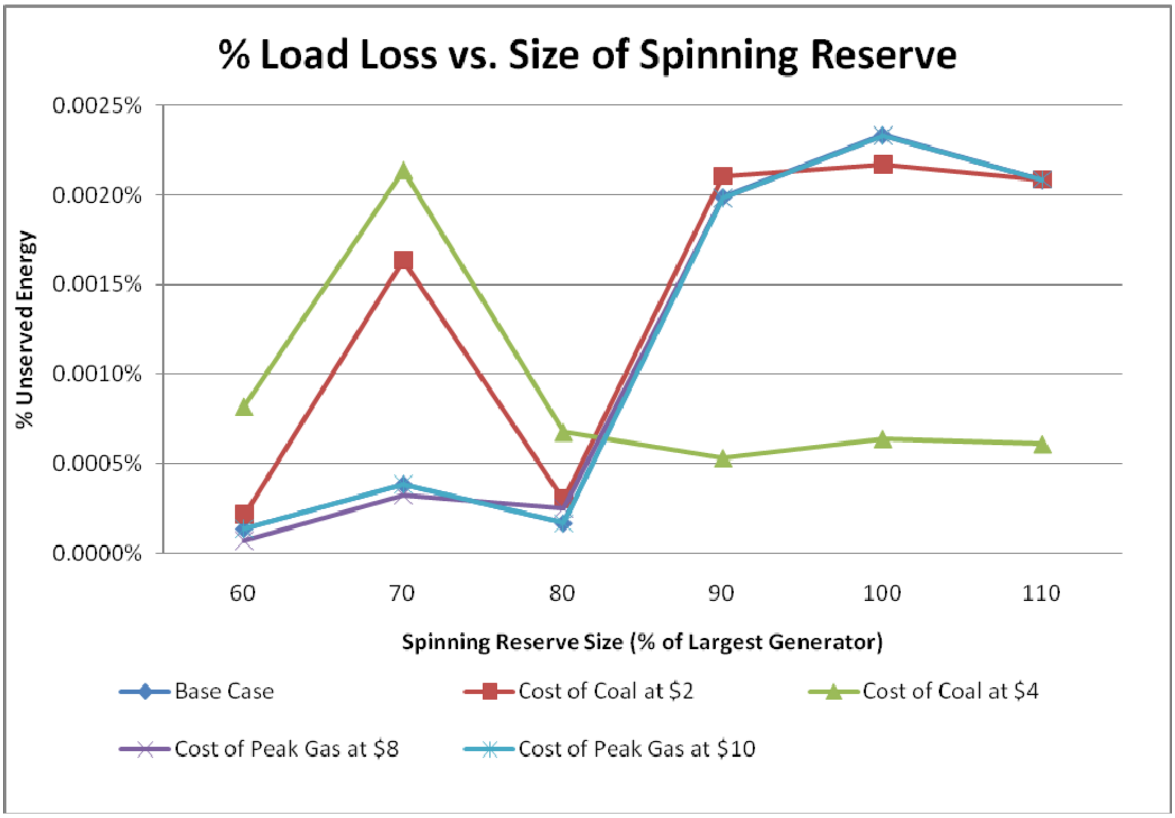


Table 2 demonstrates little variation in optimal dispatch cost between varying fuel cost assumptions.

- **Table 3 Sensitivity Analysis: Unserved Energy vs Spinning Reserve Level**



The inverse shape of the unserved energy for coal at $4 appears to be the result of the less frequent dispatch of Muja G6 with a high forced outage rate of 8.89 % under the Coal Cost of $2. This again demonstrates the sensitivity of the model to the dispatch of generation with high forced outage rates.

14.2. Methodology

14.2.1. Economic Modelling Methodology

The economic model has been established to determine the **changes in total market generation cost** for the various Ancillary Service procurement options being considered. The SKM generation dispatch tool GENESIS is used to determine the generation being procured from each generator within the market for any load. GENESIS optimises the plant mix subject to a range of technical constraints:

- Individual plant capacity, heat rate and ramp rates.
- Spinning Reserve.

- Startup and shutdown costs for individual plant.
- Fuel and operating cost for individual plant.
- Greenhouse gas caps, taxes, or trading.
- Renewable or other policy obligations.
- Plant availability, with Monte-Carlo simulation and the ability to define planned outages.

The principle output of GENESIS is the total variable cost to meet the load requirements of the system load. This variable cost can be summated for any period to provide a total variable generation cost. Different approaches to Ancillary Services are introduced into the model as changes to system Spinning Reserve requirements and generation unit dispatch constraints with the variable cost of each compared to provide. As it is the difference between options that is of interest here, the fixed costs are not modelled.

14.2.2. The Optimised Dispatch Market Cost

In undertaking the dispatch model for the WEM, SKM have modelled the theoretical variable cost of an optimised dispatch market supplied by the existing generation portfolio in the WEM. SKM believes this is the most appropriate approach to modelling the cost impact of Ancillary Services policy as the **optimised dispatch market provides both a benchmark** total market cost unaffected by day to day commercial arrangements and a theoretical lowest cost dispatch for the market to achieve. The market cost is the total variable generation cost plus the cost of Ancillary Services to the market, based on a payment of $7.5 per MWh Spinning Reserve sourced (which is based on the current annual payment for Spinning Reserve).

Fuel

Underpinning the Optimised Dispatch market is the application of **constant input coal cost and two tranche gas cost** for all machines in the market. The two tranche gas cost is to reflect the disconnect in the Western Australian gas market between long term base load contracts and short term peaking contracts. Although constant fuel costs are not the case within the Western Australian fuel markets, SKM believe it is the most appropriate basis for long term policy setting. This is because this approach will reflect the benefits of appropriate machine dispatch and investment in the most effective generation technology, these items being the most critical to the meeting the market objectives in the long term. Further, it is appropriate to assume disparities in fuel cost contracts can be traded out through secondary markets over time. That is because a less efficient generator with a cheap long term gas price may generate a better economic outcome by on selling gas at the current market price (at a margin above the long term contract).

To ensure the assumptions around fuel cost are not adversely impacting the outcomes of the study SKM has undertaken a sensitivity analysis around the fuel costs.

Bilateral Contracts

The Optimised Dispatch Model does not include the limitations placed on the dispatch of generation by existing bilateral contracts. SKM does not believe market policy should be impacted by the contractual arrangements of the day. Theoretically, over time the combination of the bilateral contracts positions and the STEM should drive the market towards an optimised dispatch.

Available data

The other advantage of the Optimised Dispatch Market cost approach is that it does not require information that existing market participants would consider highly confidential, such as the cost and structure of contracts. As such this modelling approach does not suffer from disparities in information available from various market participants.

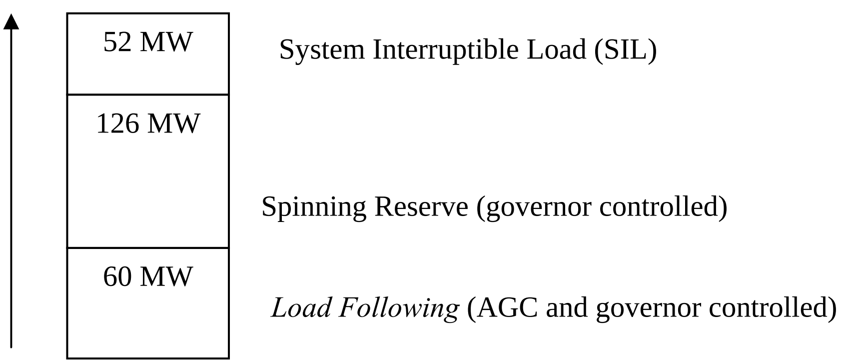
14.2.3. Modelling of Interruptible Resources

The interruptible generators on the system have been modelled by reducing the load by the output of Albany wind farm scaled to 200 MW. This coarse modelling approach was considered appropriate as the impact of changes in penetration of intermittent generation was not within the scope of this study. In effect, the intermittent resources have been modelled as an increase in variability of the system.

14.2.4. Modelling of Spinning Reserve

The Spinning Reserve currently provided on the SWIS is based on a calculation of 70% of the largest machine on the system. The Collie Coal Power station is currently the largest machine at 340 MW, and as this machine is currently high in the dispatch order the required Spinning Reserve is 238 MW. This Spinning Reserve requirement can be broken down as per the figure below.

- **Figure 14.7: Spinning Reserve in the SWIS for Collie Operational**



The Spinning Reserve and *Load Following* components of the Spinning Reserve are provided by generators on the system whilst the SIL is provided by Synergy and Kanowna. With the model, Spinning Reserve is set at the total amount of spinning reserve being carried on the system. The SIL has been modelled as a generator with 52 MW spinning reserve, with the highest run costs on the system and zero start up cost. This results in SIL being dispatched regularly for spinning reserve but not energy.

Spinning Reserve levels have been modelled from 60 % to 110 %.

14.2.5. Monte Carlo Analysis

Within GENISIS, outages for each generator in the market are modelled by randomly removing the generators from service at a level consistent with the generators forced outage rate. The ability of the system to respond is determined by the ramp rates of the machines. In the event that the system cannot respond, generation is provided by the “Lost Load” Generator. The cost of output of this generator has been set at $100,000 to ensure all technically feasible dispatch options are attempted before dispatching the VOLL generator. As such, the VOLL generator represents unserved energy on the system.

The model is dispatched repetitively using the weighted random outages until such time as the averages of 4 sets of random dispatches (Monet Carlo Loops) have Total Generation Costs with 2% of each other. At this stage the model has said to converge - these convergent dispatch sets form the basis of the results.

14.3. Model data

14.3.1. Generator Input Data

The generator input data into the economic model is provided in Appendix B.1. Each field of the generator input data sheet was filled based on the following information:

Input Data	Details
Identification	
▪ Unit ID	▪ Sequential unit ID provided between 0 and 67.
▪ Generator Name	▪ Based on information provided by the IMO (Appendix B.2).
▪ Region	▪ All generators are in the SWIS region.

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Input Data	Details
Generator Type ▪ Starting Type ▪ Fuel Type	 ▪ Slow start for Cogeneration and Coal generators Medium start for CCGT's. Rapid start for OCGT's and wind farms. ▪ Based on information provided by the IMO (Appendix B.2).
Availability ▪ Install Date ▪ Life ▪ Status ▪ Planned Outage ▪ Forced Outage	 ▪ The install date was set to 01/01/2001 for all generators. ▪ The life span for all generators was set to 60 years. This data is only used if studies were carried out for multiple years. ▪ All intermittent generators, Bluewaters Unit 1, Newgen Kwinana, Muja G1 to G4, Kwinana G5 to G6 and Perth Energy Kwinana were switched off. ▪ Set to 0% for all generators. The generator planned outages were reflected in each generator's availability where each planned outage in 2008 was modelled based on information provided by the IMO (Appendix B.3). ▪ Each generator's forced MWh outages were taken as a ratio of the maximum MWh the machine is able to dispatch. This was based on the information provided in Appendix B.3.
Outage Times ▪ Short Outage (% of Outages) ▪ Short Outage Time ▪ Moderate Outages (% of no short Outages)	Based on information provided in Appendix B.3 ▪ Was determined based on the majority of outages for each machine. ▪ Defined as the majority of short outage duration for the generator. ▪ Was determined based on the ratio of the medium duration outages to the non short outages for each generator.

SKM

Input Data	Details
▪ Moderate Outage Time ▪ Long Outage Time	▪ Defined as the majority of medium outage duration for the generator. ▪ Defined as an average of the long outage durations for the generator.
Capacity ▪ Gross Capacity ▪ Auxiliary's ▪ Gen Tx ▪ Min Gross Gen ▪ Max Net Export Capacity (MW) ▪ Min Net Export Capacity (MW) ▪ Spinning Reserve (MW) ▪ Fast Ramp Capacity (MW/Period)	 ▪ Based on data provided by the IMO (Appendix B.2). ▪ Assumed to be 0 MW for all generators. ▪ Assumed to be 0 MW for all generators. ▪ Based on data provided by System Management (Appendix B.4). ▪ Equal to the gross capacity of the generators. ▪ Equal to the min gross gen. ▪ *Dependent on study being carried out. Values used are defined in the appropriate study case description.* ▪ Based on data provided by System Management (Appendix B.4).
Fuel Costs ▪ Fuel $/MWh @ MLHR ▪ Fuel $/MWh @ FLHR	 ▪ Based on gas cost price of $4/GJ for base load gas and $9/GJ for peaking gas. Coal cost of $3/GJ was assumed typical generator heat rate curves provided in Appendix B.5. ▪ Based on gas cost price of $4/GJ for base load gas and $9/GJ for peaking gas. Coal cost of $3/GJ was assumed typical generator heat rate curves provided in Appendix B.5.

SKM

Input Data	Details
Other Cost Factors	
▪ Variable O&M Costs $/MWh	▪ $4.00/MWh for Cogen generators and CCGT's. $3.50/MWh for OCGT generators. $2.10/MWh for Coal generators.
▪ Lube Oil $/MWh	▪ Assumed to be $0.
▪ Marginal Loss Factor	▪ Assumed to be 0.
Effective Costs	
▪ $/MW.period @ MLHR	▪ Equals to the sum of Fuel $/MWh @ MLHR and Variable O&M Costs $/MWh scaled to fit a period (30 mins).
▪ $/MW.period @ FLHR	▪ Equals to the sum of Fuel $/MWh @ FLHR and Variable O&M Costs $/MWh scaled to fit a period (30 mins).
Startup Costing	
▪ Cold Start	▪ Based on data provided by the IMO (Appendix B.2) which was scaled to $/MW for each type of generation plant (Coal, CCGT and OCGT). Cogenerations plants costs were assumed to cost $100,000 per startup, to take into account link to manufacturing process.
▪ Min Cold Time	▪ Based on data provided by System Management (Appendix B.4). Shown in periods (30 mins).
▪ Warm Start	▪ Assumed to be $0.
▪ Min Warm Time	▪ Based on data provided by System Management (Appendix B.4). Shown in periods (30 mins).
▪ Hot Start	▪ Assumed to be $0.

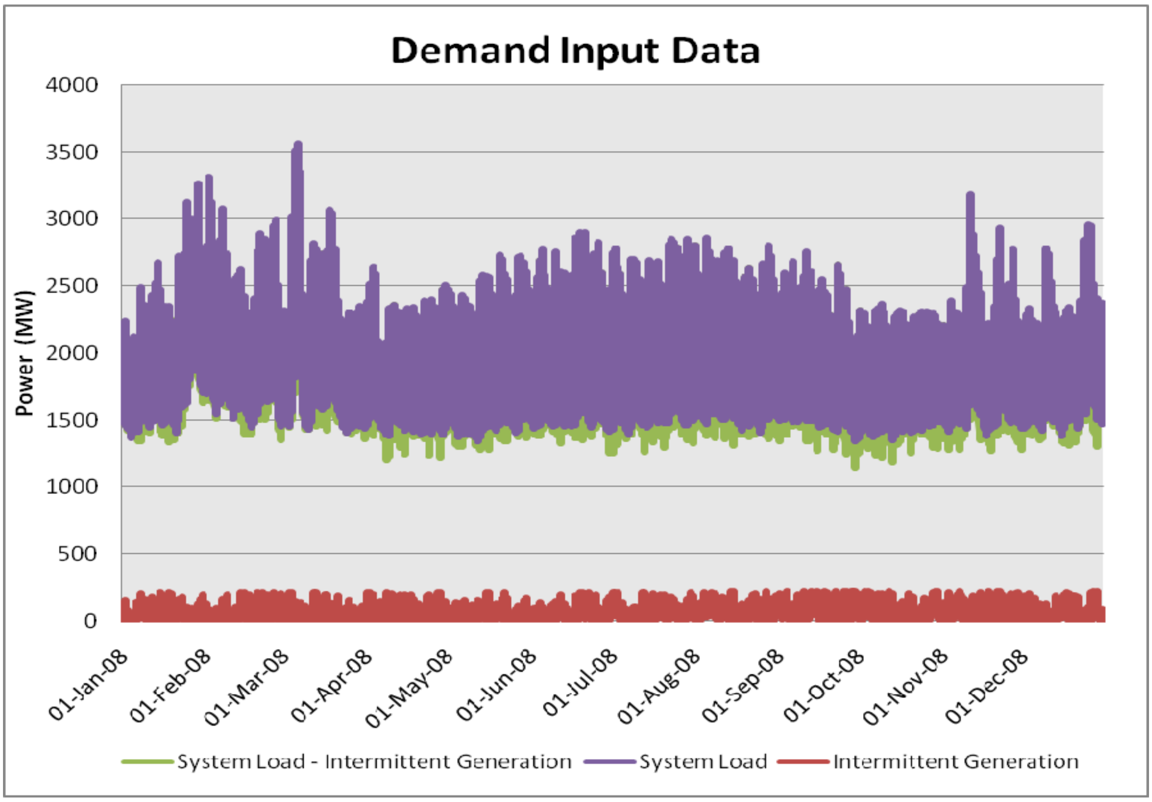
▪

14.3.2. System Load (Demand Input Data)

The demand input data is based on the following:

- All economic modelling was based on 2008 system load data provided by System Management with no scaling taken into account. The studies were carried out for year 2008 only.
- Intermittent generator output (which was based on the Albany wind farm output for 2006) was scaled to the total intermittent generation size (215.3 MW) of the SWIS and was subtracted from the total system load. The figure below describes the process carried out.

Figure 14.8: Demand Input Data



14.4. Cases Considered

Study 1 – Spinning Reserve Size (% of Largest Unit Dispatch)

The objective of this study was to determine the most efficient amount of Spinning Reserve based on the following:

1) Volume of Lost Load (VOLL)
2) Total Cost

The following methodology was used to carry out this study:

3) Set all Non-Verve Energy generators Spinning Reserve to 0 MW.
4) Set the Verve Energy generators as per the market dispatch priority obtained from the IMO.
5) Enable Monte-Carlo analysis to determine the minimum, average and maximum values for VOLL and total cost.
6) Vary the amount of Spinning Reserve of the Verve Energy generators to achieve the following:

- 60 % of the size of the largest machine
- 70 % of the size of the largest machine
- 80 % of the size of the largest machine
- 90 % of the size of the largest machine
- 100 % of the size of the largest machine
- 110 % of the size of the largest machine
- 120 % of the size of the largest machine

7) Record the results and determine variation in cost and VOLL from the current base. Graph these variations.

Study 2 – Open Market vs. Verve Energy Only Spinning Reserve

The objective of this study was to determine the difference between using all generators in the market and Verve Energy only generators. The following criteria were used to benchmark the two scenarios (Open Market (including Verve Energy) and Verve Energy only):

8) Volume of Lost Load (VOLL)
9) Total Cost

The following methodology was used to carry out this study:

10) Enable Monte-Carlo analysis to determine the minimum, average and maximum values for VOLL and total cost.
11) Set Spinning Reserves for all capable generators to their approximate Spinning Reserve capability. Coal Fired generation is set to 30 MW, all OCGT are set to Spinning Reserve to available output.
12) Set the size of Spinning Reserve required to 70 % of the largest unit dispatched.
13) Compare cost and VOLL to 70 % in study one.

Study 3 – Effect of Mid Merit Generators in the System

The objective of this study is to determine the effect of Ancillary Services being delivered through mid merit generators in the system.

14) Volume of Lost Load
15) Total Cost

The following methodology was used to carry out this study:

16) Set Spinning Reserves for all capable generators to their approximate Spinning Reserve capability.
17) Introduce a new LMS100 generator in the system to reduce a Frame 9 generator.
18) Set the size of Spinning Reserve required to 70 % of the largest unit dispatched.
19) Compare cost and VOLL to Base Case.

Study 4 - Sensitivity Analysis

The sensitivity of the fuel costs were studied by varying the following cases in Study 1:

20) the difference in cost between coal and gas by varying the cost of coal from $2 to $4 per GJ; and
21) the difference in cost between base load gas and peak load gas by varying the cost of peak gas from $7 to $9 per GJ

14.5. Model Output

The SKM GENESIS model provides the following data as an output:

- Summary sheet showing amount of energy dispatched, volume of loss load and total cost (Appendix B.6)
- Generator dispatch graph for the base case where no machines are disconnected (Appendix B.7)
- Generator statistics summaries (Appendix B.8)
- Note: The results shown in appendices B.6, B.7 and B.8 are based on the base case where the spinning reserve is set to 70. % of the largest machine and only Verve Energy generators provide spinning reserve.

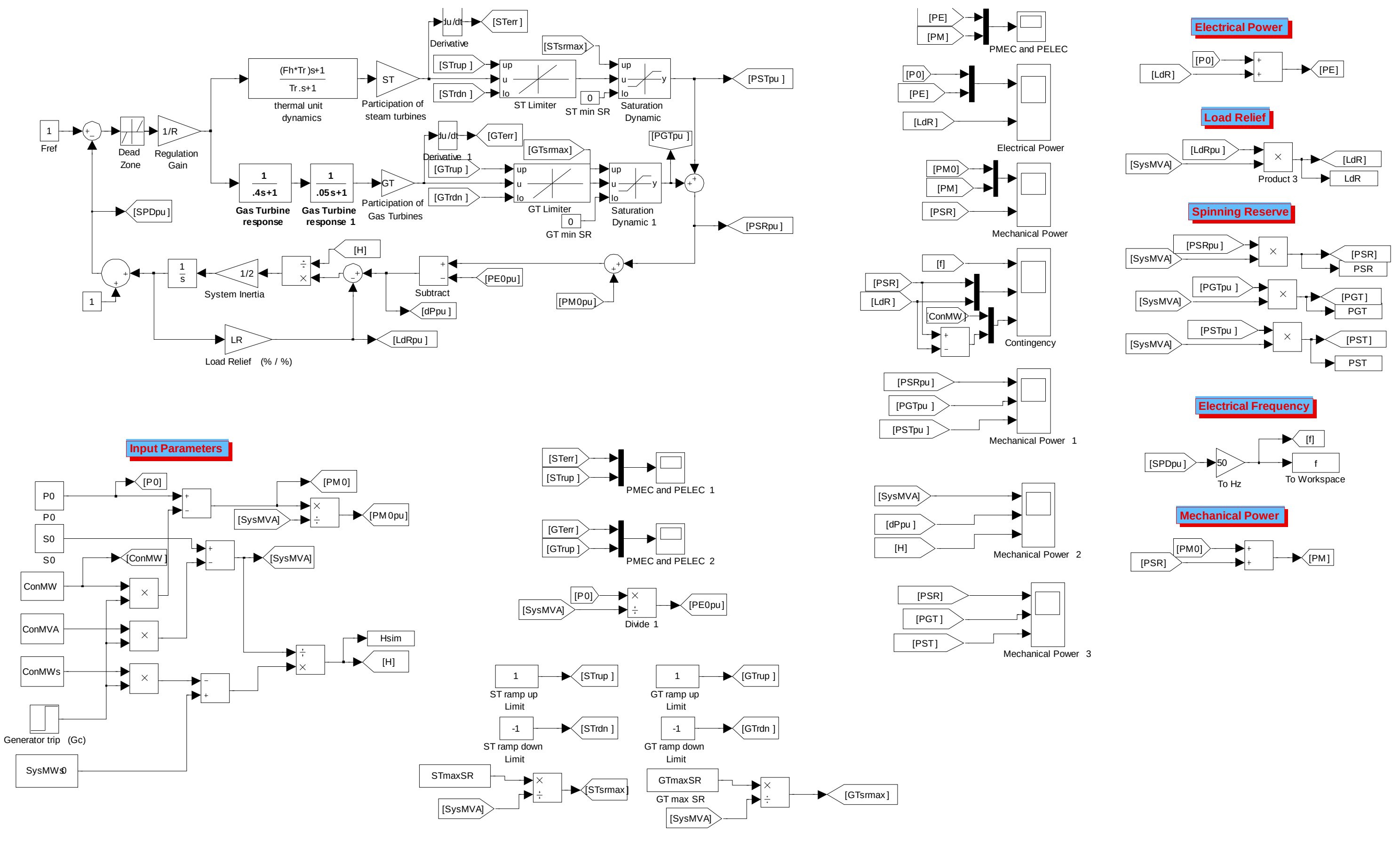
15. Abbreviations

BETTA	British Electricity Trading and Transmission Arrangements
Cogen	Cogeneration Facility (generation waste heat used for other purposes)
EGC	Electricity Generation Company (Verve Energy)
ERA	Economic Regulation Authority
FCAS	Frequency Control Ancillary Service
FOR	Forced Outage Rate
GJ	Giga Joule
ICR	Instantaneous Control Reserve
IMO	Independent Market Operator
kA	Kiloamps
kV	Kilovolts
kW	Kilowatts
kWh	Kilowatt-hours
LMS100	General Electric 100 MW Aero-derivative generator.
ms	Milliseconds
MW	Megawatts
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
PLC	Programmable Logic Controller
PSOP:AS	Power System Operating Procedure: Ancillary Services
RCM	Reserve Capacity Mechanism
SCADA	Supervisory Control And Data Acquisition
SCGT	Simple Cycle Gas Turbine
SIL	System Interruptible Load
SKM	Sinclair Knight Merz

STEM	Short-Term Energy Market
SWIS	South West Interconnected System
VOLL	Value of Lost Load
WA	Western Australia
WEM	Wholesale Energy Market
WTG	Wind Turbine Generator

Appendix A: Details of System Response Modelling

- **Figure 0.1 Full Matlab Simulation Model**



SINCLAIR KNIGHT MERZ

The following is the file used to define the range of system conditions to be simulated

```
function y = generationlooper()

clear

file = fopen('output_looper.csv','w');
file_line='Demand,GTsrMVA,STsrMVA,Contingency,SR_Required,SR_Delivered,SR_STexpected,SR_STactual,SR_GTexpected,SR_GTactual,LoadRelief,f_min,t_min,H';
fprintf(file,'%s', file_line);

   H=5.1;
   ConMVA=412.5;
   ConMW=343;
   ConMWs=ConMVA*2.9;
   LR=1;    % Load Relief coefficient (%/%)
   R=0.05;  % Governor Droop

for Demand=1500:100:4000
   Demand
   SysMWs0=0;
   SRreq=240;
   GTsrMVA=0;
   STsrMVA=0;

   for GTsrMVA=0:100:1000
      for STsrMVA=0:100:1000
         %for SRreq=200:40:320
         SysMVA=(Demand/0.9+GTsrMVA+STsrMVA);
         ST=STsrMVA/(SysMVA-ConMVA);
         GT=GTsrMVA/(SysMVA-ConMVA);
         assignin('base','H',H);
         SysMWs0=SysMVA*H;
         if ST+GT ~= 0
            STmaxSR = ST/(ST+GT)*SRreq;
            GTmaxSR = GT/(ST+GT)*SRreq;
         else
            STmaxSR = 0;
            GTmaxSR = 0;
```

```
    end

    STexp = STmaxSR;
    GTexp = GTmaxSR;
    STmaxSR = 1000;
    GTmaxSR = 1000;

    assignin('base','SysMWs0',SysMWs0)
    assignin('base','ConMW',ConMW)
    assignin('base','ConMVA',ConMVA)
    assignin('base','STmaxSR',STmaxSR)
    assignin('base','GTmaxSR',GTmaxSR)
    assignin('base','ConMWs',ConMWs)
    assignin('base','P0',Demand)
    assignin('base','S0',SysMVA)
    assignin('base','GT',GT)
    assignin('base','ST',ST)
    assignin('base','LR',LR)
    assignin('base','R',R)
    assignin('base','Tr',10)      % Reheat time constant seconds
    assignin('base','Fh',0.3)     % Fraction of total power generated by the HP turbine
    assignin('base','GTsrMVA',GTsrMVA)
    assignin('base','STsrMVA',STsrMVA)
    sim('freq',40);               %call simulink
    fmin=min(f);
    tmin = 0;
    for counter=1:length(f)
        if f(counter) == fmin
            tmin=tout(counter);
            idx = counter;
            break
        end
    end

fprintf(file,'\n%g,%g,%g,%g,%g,%g,%g,%g,%g,%g,%g,%g,%g,%g',Demand,GTsrMVA,STsrMVA,ConMW,SRreq,PSR(idx),STexp,PST(idx),GTexp,PGT(idx),LdR(idx),fmin,tmin,Hsim(idx));
  %end
  end
 end
```

```
end

fclose(file)
```

Appendix B: Economic Modelling Information

Specifically excluded from public version