Reliability Panel
AEMC

PANEL
DETERMINATION

Reliability Panel AEMC

DRAFT DETERMINATION

Review of the System Restart Standard

25 August 2016

Submissions due 6 October 2016. Reference: REL0057
Draft Determination

Inquiries

Australian Energy Market Commission
PO Box A2449
Sydney South NSW 1235

E: aemc@aemc.gov.au
T: (02) 8296 7800
F: (02) 8296 7899

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About the AEMC

The AEMC reports to the Council of Australian Governments (COAG) through the COAG Energy Council. We have two functions. We make and amend the national electricity, gas and energy retail rules and conduct independent reviews for the COAG Energy Council.

Executive Summary

The Reliability Panel (Panel) has prepared this draft determination on the System Restart Standard (Standard) Review 2016.

Under National Electricity Rules (Rules), the Panel is required to determine, modify as necessary and publish the Standard. The terms of reference for this review were provided by the Australian Energy Market Commission (AEMC) following amendments to the Rules in 2015 which changed governance, procurement and cost recovery frameworks for system restart ancillary services (SRAS).

What is the Standard?

The Standard specifies the time, level and reliability of restoring the generation and transmission system following a major supply disruption that results in an uncontrolled full or partial power outage in one or more electrical sub-networks[1] in the NEM.[2] As such the Standard provides a target for the procurement of SRAS by the Australian Energy Market Operator (AEMO). It is a procurement standard rather than an operational standard.

SRAS is the capability of a generator to restart following a major supply disruption where all other generators in the same part of power system have tripped and are generally unable to restart because they cannot obtain an external supply of energy from the transmission network. Not all generators have this capability given the additional cost this capability creates for a generator. SRAS acts a failsafe or 'back up' service that provides a dependable 'restart' capability. It is only expected to be required infrequently. This is because AEMO has access to a number of processes and systems to manage and operate the power system so it remains in a secure and reliable state. SRAS has never been used since the start of the NEM in 1998.

What the Standard does not specify

The goal of the Standard is to ensure sufficient generation and transmission network capability is restored to ensure that the consumer load can be reconnected in a prompt and effective manner.

However, the Standard does not specify the level of load (consumer consumption) that needs to be restored. The Rules outline what the Standard must cover and specifying the time in or level to which load must restored is not required by the Rules. The Panel also considers it is more appropriate to define the Standard, and hence the appropriate level of SRAS procurement, in terms of restored supply to the generation and transmission system. This is because it is the network operators who are responsible for reconnecting consumers and reconnection can be dependent on a great variety of issues

1 In order to ensure that SRAS is available near all the major centres of generation, the NEM is divided into electrical sub-networks. The boundaries for the individual electrical sub-networks are determined by AEMO based on guidelines included in the Standard. Currently, there is one sub network in each NEM region, with the exception of Queensland which is divided into two.

2 This is often referred to as a 'black system'. A black system is defined in the NER as "The absence of voltage on all or a significant part of the transmission system or within a region during a major supply disruption affecting a significant number of customers."

that are beyond the scope of the Standard.[3] It would be difficult and not helpful for AEMO to be required to estimate the time to do this and provide for it when it is procuring required SRAS.

The Draft Standard

The current Standard applies equally in each electrical sub-network and requires AEMO to procure SRAS sufficient to restore generation and transmission such that 40 per cent of peak demand in that sub-network could be supplied within four hours of a major supply disruption occurring.

The Draft Standard differs from the current Standard in a couple of key ways:

- under the Draft Standard different 'levels' of the Standard can apply in different parts of the NEM, referred to as electrical sub-networks. That is, the time, level and reliability of restoring the generation and transmission system can differ from one sub-network to another. The Panel tailored the level and time components of the Standard for each electrical sub-network to reflect the speed at which the generation can be restored, the characteristics of the transmission network and the economic circumstances that apply to the sub-network. In addition, the Panel expressed the level component of the Draft Standard in relation to the average operational demand, instead of the current specification of peak demand. The Panel considers that the average operational demand is relatively stable over time as it is does not vary significantly between years due to extreme weather. The Draft Standard will provide an efficient level of SRAS procurement and an expected speed of restoration that matches the limitations and the economic consideration of each of the electrical sub-networks.
- • the Draft Standard now includes an aggregate reliability level for the restoration of each of the electrical sub-networks. Aggregate reliability refers to the total reliability of SRAS procured for a sub-network rather than the reliability of each of each individual SRAS sources procured for the sub-network. The aggregate reliability will be an important driver for AEMO to procure a level of SRAS that efficiently balances the costs of additional SRAS and the expected benefits that the additional SRAS provides to consumers through a more reliable restoration process. This may expand the range of restart services that AEMO can choose from when procuring SRAS to meet the Standard.

The table below provides the time, level and reliability of restoring the supply in each electrical sub-network that the Panel determined for the Draft Standard. The levels of the Draft Standard reflect the technical capability of the generation and network in the sub-networks while the aggregate reliability level targets an efficient level of SRAS procurement.

The Draft Standard also includes a requirement to:

> "Re-supply and energise the auxiliaries of at least 500 MW of generation capacity north of Sydney within 1.5 hours of a major supply disruption with an aggregate reliability of at least 75%."

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3 Reconnection of consumers takes place in accordance with a system restart plan and specific procedures developed by network providers.

This requirement is made as a delay to supplying the auxiliaries of the New South Wales generators north of Sydney would significantly delay the restoration of the sub-network, due to the large distance between these generating units and the generation in the south of the sub-network.

Draft Guidelines for the determination of electrical sub-networks

The Standard also includes Guidelines:

- to guide AEMO when it defines the boundaries of the electrical sub-networks. The Panel amended these draft guidelines for the Draft Report to include an additional requirement that a resultant sub-network be able to operate securely after being restored; and
- for the treatment of diversity (of electrical, geographical and energy source) between the SRAS sources within an electrical sub-network. The Panel amended these draft guidelines for the Draft Report to specifically consider diversity when it assesses the aggregate reliability of each sub-network.

Determining the Standard

The Panel determined the Draft Standard by considering how to minimise the expected costs of a major supply disruption, including the cost impact on consumers of a disruption and the cost of procuring SRAS. In doing so the Panel was informed by:

- technical advice from AEMO, which included the impact of different levels of SRAS procurement on the restoration process;
- an economic assessment of different levels of SRAS procurement to estimate the economic value of procuring these differing levels of SRAS;
- a review of international experience of major blackouts and associated regulatory arrangements. This has allowed the Panel to determine a Draft Standard that is equivalent to, or better than in some respects, the world's best practice requirements for system restoration.

The Draft Standard has also been determined on the assumption that when restoring supply to the generation and transmission system in a sub-network, supply from a neighbouring sub-network cannot be relied on by AEMO when procuring sufficient SRAS. This assumption is enshrined in the Rules. The Panel recognises that this assumption is conservative, as generally it is likely that supply from neighbouring sub-network would be available. However, by basing the Draft Standard on such an assumption, the procured SRAS is evenly distributed throughout the NEM and will also provide greater assurance against the very unlikely occurrence of a major supply disruption affecting the whole NEM.

The Panel is seeking stakeholders' views on all aspects of the Draft Standard. Submissions from stakeholders are due by 6 October 2016 and the Panel intends to hold a Public Forum on 21 September 2016.

Draft Standard - Time, Level and Aggregate Reliability by Electrical Sub-Network

Electrical Sub-Network	Level of Restoration (% of Average Operational Demand)	Restoration time (hrs)	Aggregate Reliability
North Queensland	45%	4.0	90%
South Queensland	25%	3.0	90%
New South Wales	20%	3.0	90%
Victoria	20%	3.0	90%
South Australia	25%	3.0	90%
Tasmania	30%	3.0	90%

Reliability Panel members

Neville Henderson, Chairman and AEMC Commissioner

Trevor Armstrong, Acting Chief Executive Officer, Ausgrid

Lance Balcombe, Chief Executive Officer, TasNetworks

Murray Chapman, Executive Officer Corporate Development, Australian Energy Market Operator

Mark Collette, Energy Executive, Energy Australia

Royce De Sousa, General Manager - Energy & Sustainability, Visy

Gavin Dufty, Manager Policy and Research, St Vincent de Paul Society, Victoria

Miles George, Managing Director, Infigen Energy

Chris Murphy, Strategic Advisor, Meridian Energy and General Manager - Energy Market Interfaces, Telstra

Richard Wrightson, General Manager Energy Portfolio Management, AGL Energy

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1 Introduction

The Reliability Panel (Panel) has been directed by the Australian Energy Market Commission (AEMC) to undertake a review of the System Restart Standard (Standard) in accordance with its responsibilities under the National Electricity Rules (Rules).[4] The Panel's draft findings are set out in this report and the Panel invites comments from stakeholders on its draft findings.

1.1 Review of the System Restart Standard

The Standard sets out several key parameters for power system restoration of the National Electricity Market (NEM) in the event of a major supply disruption, including the restoration time and level of available supply from the restored generation and transmission network.[5] It is a standard against which the Australian Energy Market Operator (AEMO) procures System Restart Ancillary Services (SRAS) from contracted SRAS providers, such as generators with SRAS capability.[6] SRAS are special generation services that AEMO may call upon to assist in the restoration of supply[7] following an uncontrolled failure of the power system, which results in a loss of supply to a large number of customers, such as an entire electrical sub-network.[8] In the event of a major supply disruption, SRAS may be called on by AEMO to supply sufficient energy to restart power stations in order to begin the process of restoring the power system. AEMO must prepare the System Restart Plan in accordance with the Standard.[9]

The Standard does not set out the process of restoration of supply to consumers directly following blackouts within a distribution network or on localised areas of the transmission networks. There is a separate process that has been developed with input of jurisdictional governments to manage any disruption that involves the operator of a network having to undertake controlled shedding of customers.

Restoration from these localised or controlled events is not considered in the Standard, and is not considered in this review.[10]

4 Clause 8.8.3(a)(5) of the Rules.

5 Clause 8.8.3(aa) of the Rules.

6 Clause 3.11.7(a1) of the Rules.

7 Supply is defined in chapter 10 of the Rules as “the delivery of electricity”

8 A sub-network is part of a network defined by AEMO using guidelines included in the Standard such as the concentration of load and generation, as well as the structure of the network. Currently, there is one sub network in each NEM region, with the exception of Queensland in which there are two. A sub-network is part of a network defined by AEMO using guidelines included in the Standard such as the concentration of load and generation, as well as the structure of the network. Currently, there is one sub network in each NEM region, with the exception of Queensland in which there are two.

9 Clause 4.8.12(c) of the Rules.

10 AEMO may shed load in order to maintain power system security. This process, and the subsequent restoration of shed load, is developed with input of jurisdictional governments to manage any disruption that involves the operator on a network having to undertake controlled shedding of customers. It is not relevant to the Standard and is not considered in this review.

The Standard also sets out other matters that AEMO must consider, including SRAS diversity considerations[11] and guidance on the boundaries of electrical sub-networks.

1.2 Requirements of the Review

On 30 June 2015, the Australian Energy Market Commission (AEMC) provided Terms of Reference to the Panel to initiate a review of the Standard (the Review). The Panel's Terms of Reference requires the Panel to consult with as wide a range of stakeholders as possible, including Network Service Providers, Generators, consumers, jurisdictional governments and any other relevant bodies.[12]

The Terms of Reference require the Panel to undertake a review of the Standard to meet the requirements established in clause 8.8.3(aa) of the Rules, which were revised in July 2015 following a final rule determination made by the AEMC. [13]

The Panel's review does not consider processes for reconnecting consumers' load following a normal supply disruption as there are existing arrangements for reconnecting load. In addition, the review does not consider how AEMO has applied the current Standard, including the current level of SRAS procurement. AEMO is required to meet the Standard and the Australian Energy Regulator (AER) is responsible for enforcing compliance with this requirement.

The outcome of the review is a Standard that will guide AEMO to procure a level of SRAS that better reflects the balance to stakeholders of the benefits of procuring SRAS against the costs.

The Terms of Reference require the Panel to complete its Review by December 2016. This timing allows AEMO to subsequently develop SRAS Guidelines that are consistent with any amendments to the Standard that may result from this Review, and before AEMO begins the process for SRAS procurement for the period commencing July 2018.

1.3 Timetable for the Review

In carrying out this Review, the Panel is required to follow the consultation process set out in clause 8.8.3 of the Rules along with the specific requirements set out in the Terms of Reference. The Panel published an issues paper on 19 November 2015 to seek stakeholder views on the issues related to the Review. Eleven submissions were received from industry and consumer representatives, with a summary of these submissions and the Panel’s comments included in Appendix B.

In April 2016 the Panel held briefings with each of the Jurisdictional System Security Coordinators (JSSCs),[14] including in some cases representatives from the regional Transmission Network Service Provider and other State Government representatives, to

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11 SRAS diversity considerations currently include electrical, technological, geographical and fuel matters.

12 The Terms of Reference is available on the REL0057 project page on the AEMC website.

13 AEMC, System Restart Ancillary Services Rule Change, Final Determination, 2015.

14 The Jurisdictional System Security Coordinator is appointed by the Minister under the National Electricity Law. Under the NER, AEMO must coordinate with the JSSC in relation to a number of power system security matters.

discuss regionally specific issues. The Panel then held a public forum on 27 April 2016 to discuss stakeholder views relating to the Standard.

The Panel will undertake further consultation with stakeholders through seeking comments and submissions on this draft determination. The Panel will also carry out further meetings with stakeholders and facilitate discussion on the revised Standard at a public forum on 21 September 2016.

The following table outlines the key milestones and dates leading to the delivery of the Panel's final report to the AEMC.

Table 1.1 Timetable for the Review

Milestone	Date
Publication of Issues Paper	19 November 2015
Close of submissions to Issues Paper	18 December 2015
Public Forum – Issues raised	27 April 2016
Publication of DGA's Report – International Comparison of Major Outages and Restoration	19 May 2016
Publication of draft determination and Draft Standard	25 August 2016
Public Forum – draft determination and Standard	21 September 2016
Close of Submissions to draft determination	6 October 2016
Final determination and Standard	17 November 2016

1.4 Specialist Advice

In addition to consulting with key stakeholders, the Panel also obtained specialist advice from DGA Consulting, AEMO and Deloitte Access Economics, as summarised below.

Advice on international experience of major blackouts and associated regulatory arrangements

- The Panel received advice from DGA Consulting on international experience from a comparison of five major overseas blackouts and a comparison of the regulatory arrangements in five jurisdictions to prevent or mitigate major blackouts.

AEMO advice

- AEMO provided the Panel technical advice in relation to the restoration of each electrical sub-network under a range of SRAS procurement options.

- AEMO also provided the AEMC, in its role as Reliability Panel secretariat, with confidential cost information for the procurement of SRAS, which was used by Deloitte Access Economics in its report on the economic assessment of SRAS.

Economic advice

- Deloitte Access Economics provided the Panel advice in relation to the level of SRAS procurement in each electrical sub-network that would be expected to minimise the costs of a major supply disruptions under the range of SRAS procurement options.
- The Panel consulted with the JSSCs to validate some of the key assumptions used in the economic assessment of the Draft Standard.

1.5 Submissions on the Panel's draft determination

The Panel invites written submissions on this draft determination and Draft Standard from interested parties by no later than 6 October 2016. All submissions received will be published on the AEMC's website (www.aemc.gov.au), subject to any claims for confidentiality.

Electronic submissions must be lodged online through the AEMC's website using the link entitled "lodge a submission" and reference code "REL0057". The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated.

Upon receipt of electronic submissions, the AEMC's website will issue a confirmation email. If this confirmation email is not received within three businesses days, it is the submitter's responsibility to ensure the submission has been delivered successfully.

If choosing to make submissions by mail, the submission must be on letterhead (if submitted on behalf of an organisation), signed and dated. The submission may be posted to

Reliability Panel
PO Box A2449
Sydney South NSW 1235
Or by Fax to (02) 8296 7899.

1.6 Structure of the draft determination

The remainder of this draft determination is structured as follows:

- Chapter 2 describes the background relevant to understanding the Standard, including how system restart operates, and how the Standard fits into the overall governance arrangements for the restoration of the NEM power system;
- Chapter 3 sets out the assessment criteria used by the Panel for the review of the Standard;
- Chapter 4 sets out a summary of the Panel's approach to the economic assessment of the Draft Standard, the international experience from other jurisdictions and the advice provided by AEMO;
- Chapter 5 summarises the results of the Panel's cost benefit assessment of SRAS;

- Chapter 6 discusses the structure and settings in the new standard; and
- Chapter 7 describes a number of issues raised in the review that lie outside the scope of the Terms of Reference but that the Panel recommends for further consideration.

2 Background

The NEM power system has historically delivered a safe, secure and reliable supply of electricity to consumers. This has been achieved through the operational frameworks established in the Rules that provide clear guidance to AEMO for managing the power system within a secure operating state. While unplanned events can and do occur in the NEM power system, these frameworks contain mechanisms to stabilise the system following such events and maintain continued supply to consumers.

These operational frameworks are effective in maintaining the power system for the majority of events, and hence for most of the time. However, certain severe and unpredictable events have the potential to disturb the power system to an extent that cannot be managed by these frameworks. These rare events can potentially result in a major supply disruption[15] that shuts down entire sections of the power system, with significant economic cost impacts for a large number of consumers.

In order to manage the extent of these costs and to return supply to consumers, the Rules set out a process for restoring the power system following a major supply disruption. This includes AEMO's procurement of system restart ancillary services (SRAS)[16] and its plan to coordinate the various parties to restore the power system. The Panel is responsible for determining the Standard, which is central to this process of system restoration. The Standard guides AEMO's procurement of SRAS by defining the high level target for how fast and reliably the system should be restored.

This chapter provides an overview of how the power system is restored following a major supply disruption, summarising the:

- frameworks that maintain the power system and prevent power supply interruptions during normal operation;
- nature and consequences of major supply disruptions;
- role of SRAS in restoring supply;
- overall process of system restoration; and
- governance arrangements and responsibilities of various parties during a system restoration.

This chapter also provides a brief overview of previous work undertaken by the Panel, the AEMC and AEMO in regards to the procurement of SRAS and the restoration of the power system following a major supply disruption.

15 Major supply disruptions are defined in the Rules as the unplanned absence of voltage on a part of the transmission system affecting one or more power stations and which leads to a loss of supply to one or more loads. Major supply disruptions are discussed in more detail later in this chapter.

16 SRAS are defined in Chapter 10 of the Rules as "A service provided by facilities with black start capability which allows: (a) energy to be supplied; and (b) a connection to be established, sufficient to restart large generating units following a major supply disruption."

2.1 Major Supply Disruptions and SRAS

This section provides an overview of how power supply is maintained in the NEM, the nature of a major supply disruption and how the power system can be restored following a major supply disruption.

2.1.1 Common supply interruptions

Supply disruptions can occur for a range of reasons. They vary from an interruption of supply to a small number of distribution connected customers, to a major loss of supply from the transmission network, potentially causing a widespread blackout affecting one or more regions of the NEM.

Small supply interruptions in the distribution networks are more common than larger transmission interruptions. Generally only a small number of customers are affected and supply can usually be restored within a few hours.[17] Larger supply interruptions can also occur in distribution networks during storms or bushfires. Supply interruptions within a distribution network are managed by the Distribution Network Service Provider (DNSP), but may require coordination with the Transmission Network Service Provider (TNSP) when larger disruptions occur.

A loss of supply from the transmission network is much less common than a loss of supply from a distribution network. This is because there is generally more redundancy and because the transmission assets are normally less susceptible to disruption. However, the interruptions in the supply from a transmission network usually affect many more consumers. The Standard is concerned with restoration of supply from a major supply disruption. This is discussed further in section 2.1.3.

2.1.2 Maintenance of a secure system

In order to reduce the likelihood of a major interruption to the supply of electricity to consumers, AEMO is required to maintain the NEM transmission network in a secure operating state. This means that supply disruptions to consumers should not occur as a result of any single credible contingency, where a credible contingency event is an event AEMO considers reasonably possible to occur.[18]

As AEMO is only expected to consider credible contingencies when maintaining system security, there is a residual risk of major supply disruptions following a severe non-credible or multiple contingency events, such as the loss of transmission lines during bush fires or storms, and the simultaneous tripping of multiple generating units. Therefore, in addition to maintaining system security, the risk of major supply disruptions following multiple contingencies is also managed through a number of other mechanisms in the NER, including:

17 Distribution networks generally contain some level of redundancy so that the required distribution reliability targets can be met. However, in some remote rural parts of the network there may be less redundancy due to cost.

18 Clause 4.2.3(b) defines a credible contingency event as a contingency event the occurrence of which AEMO considers to be reasonably possible. Examples of credible contingencies include the loss of a single transmission line or transformer, or the tripping of a single generating unit.

- AEMO's power to issue directions and instructions to return the power system to secure operating state;
- various emergency control schemes, including the under frequency load shedding schemes that are designed to mitigate the risk of a cascading collapse of the system frequency; and
- network protection systems that are designed to isolate regions that are experiencing a severe major supply disruption from the remainder of the NEM to prevent the disturbance from propagating beyond the affected region.

2.1.3 Major supply disruptions

When an event in the power system causes the loss of one or more power stations and the loss of supply to one or more loads, this is defined as a major supply disruption.[19] Where a major supply disruption affects a large portion of a region it is also defined as a black system condition.[20]

While the risk of major supply disruptions cannot be wholly eliminated, they are relatively rare and should only occur following severe non-credible or multiple contingency events.[21] They are potentially initiated by diverse and unpredictable events. While mitigation processes and procedures generally exist to guard against such occurrences, major supply disruptions still have the potential to occur due to an unforeseen series of improbable events, such as equipment failures or human errors.

Major supply disruptions are rare by international standards, but serious consequences and threats to life and the economy can result when they do occur. For example, one of the most prominent major supply disruptions occurred in North America in 2003, where 50 million people lost power for up to two days. This was estimated to have cost around $6 billion at that time and contributed to 11 deaths. A discussion on some international major supply disruptions is provided in Chapter 4, while the economic and societal costs of a major supply disruption are discussed in more detail in Chapter 5 of this draft determination.

Since the commencement of the NEM, there has only been one black system condition declared. This occurred in northern Queensland in 2009. This event was caused by a

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19 Chapter 10 of the Rules defines a major supply disruption as "the unplanned absence of voltage on a part of the transmission system affecting one or more power stations and which leads to a loss of supply to one or more loads."

20 Chapter 10 of the Rules defines a black system condition as: The absence of voltage on all or a significant part of the transmission system or within a region during a major supply disruption affecting a significant number of customers. Under its Power System Security Guidelines, AEMO declares a black system when 60% of predicted regional load is interrupted with one or more power stations affected (the criterion for Queensland differ slightly).

21 In principle the risk of major supply interruptions could be reduced if the criteria for classifying contingencies as credible were made broader. However, this would not be economic, as treating a contingency as credible can impose a significant impact on the way AEMO would need to operate the network. This would normally mean AEMO being required to impose tighter constraints on the transmission network power flows and/or procuring greater quantities of ancillary services, which mean lower utilisation of the transmission network assets, potentially reducing reliability to customers and increasing wholesale prices.

non-credible contingency event.[22] In this case supply to the affected area was restored by progressively reconnecting the transmission network from the operating power system in central Queensland. There has never been an event in the NEM that has required the system to be restarted using SRAS units with black start capability.

As occurred in Queensland in 2009, it is most likely that following a major supply disruption, the majority of the remainder of the power system will remain in operation. Where this occurs, supply to most consumers can usually be restored relatively quickly (provided there is not extensive damage to the network), by re-energising the affected portion of the power system from the remainder of the network. However, it is also possible that supply may not be readily available from a neighbouring part of the network. In this case, power may be needed from SRAS to promptly commence the process of re-energising the power system.

2.1.4 System Restart Ancillary Services

Although most major supply disruptions are likely to be restricted to a single part of the network, a small risk remains of a more severe event that could result in multiple parts of the network collapsing to a black system condition. In such an occurrence, supply would not be readily available from neighbouring parts of the networks for re-energising the network and restoring generation and load. Therefore, it is important that a black start capability[23] is maintained by number of generating units throughout the NEM, particularly due to the high economic and societal costs of an extended major supply disruption.

Under a black system condition, the power system voltage has collapsed to a state of zero, resulting in most or all the generating units tripping off the system. These generating units require energy to restart. However, as this energy is not available from the transmission network, it would need to come from:

- another part of the transmission network that is unaffected. However, this could take many hours if this is a long distance away, and relies on the interconnecting network being undamaged;
- an isolated pocket of generation and load that remained operating within the affected region; or
- one of the limited number of generating units with black start capability, that is, units that can restart without drawing supply from the transmission system.

AEMO is responsible for procuring SRAS from some of the generators in the NEM that have a black start capability. These procurement contracts put an obligation on those generators to maintain the capability of the contracted SRAS sources, as well as to perform regular testing and staff training to support this capability.

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22 NEMMO, Power system incident report: Black System Condition in North Queensland on 22 January 2009, NEMMCO 2009.

23 Chapter 10 of the Rules defines black start capability as a capability that allows a generating unit, following its disconnection from the power system, to be able to deliver electricity to either its connection point or a suitable point in the network from which supply can be made available to other generating units, without taking supply from any part of the power system following disconnection.

Examples of generating units that could potentially provide SRAS include:

- selected hydro generating units, gas turbines or diesel generating units that have the equipment necessary to restart with drawing supply from the network; and
- large thermal (coal or gas) generating unit with a trip to house load (TTHL) scheme designed to reduce the unit's output to match its auxiliary load when it is tripped from the network during a major supply disruption, thus being able to remain in operation and available to re-energise the network when required.[24]

In each case an SRAS source needs to have sufficient capacity to restart other nearby generating units, once they are connected. Prospective SRAS sources need to demonstrate this capability to AEMO before being considered for a procurement contract.[25]

In many ways, SRAS functions like an "insurance policy" that is designed to manage the costs associated with a major supply disruption. The income received by the generators that provide the SRAS is intended to cover their costs and to provide an incentive to continue to provide the service, as well as to provide an incentive to invest in black start capability in the future from new or existing generating units.

Procuring additional SRAS sources may help to improve the restoration process described in section 2.1.5This can occur by providing redundancy, while procuring SRAS at more than one location in the network may increase the speed of the restoration process if different power stations can be restarted in different parts of the transmission network. However, as described below, SRAS provides only the initiation of the restoration process, with many other factors and parties playing a role in restoring supply of electricity to consumers.

2.1.5 Major Supply Disruption Restoration Process

Following a major supply disruption requiring SRAS, the process to restore supply to consumers is complex and can be prolonged.

Firstly the supply to the auxiliary loads[26] at selected power stations needs to be re-established so that they can be restarted.[27] Following the restarting of these power stations, the remainder of the required power stations can be restarted and the consumer load supplied. Table 2.1 provides an overview of the restoration process, including a description of each of the three main stages of the process.

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24 Most generating units are designed to shut down when the power system frequency is collapsing during a major power system incident. However, some generating units have the capability to remain operating and supplying their auxiliary loads following a system frequency collapse, referred to as trip to house load. In practice trip to house load schemes do not always operate as expected.

25 The AEMO SRAS Guidelines defines the detailed requirements for SRAS.

26 Auxiliary load is the load from equipment used by a generating system for ongoing operation. Auxiliary loads are usually located on the generating system's side of the connection point and can include loads to operate associated co-located coal mines.

27 All power stations include auxiliary loads that are necessary for the operation of the associated generating units. Examples of such loads include the fans, conveyers and coal processing equipment, as well as various control and monitoring systems.

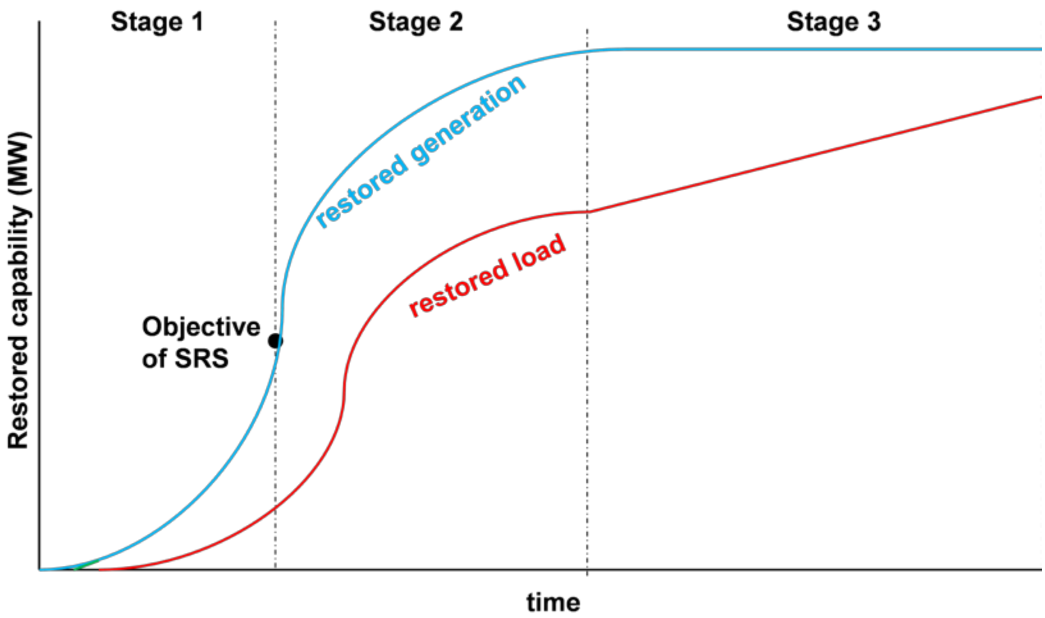
Table 2.1 Summary of the restoration process

	Stage 1 - restart system	**Stage 2 – restore generation**	**Stage 3 – restore load**
Primary focus	To restart the affected system and supply to the major power stations' auxiliary loads	To restart all the major power stations that will be required to meet the consumer load	To restore supply to the remainder of the consumer load
System operator and generation activities	• Initial assessment of events and system conditions • If possible, begin restoring the transmission network from a neighbouring network • Initiate the operation of available SRAS sources if necessary, or when they would increase the speed of the restoration process • Supply auxiliaries of selected generating units • Restart the selected generating units.	• Commence restarting all the required generating unit • Synchronise units when ready • SRAS sources may be turned off if no longer required	• Energise the remainder of the transmission and distribution network, and to restore supply to the remainder of the consumer load
Network energisation	• Initially only the minimum network is energised to manage the voltage level • The transmission network is progressively energised to be able to energise the auxiliaries of other power stations	• Most, or all, the undamaged transmission network is energised • Energise more distribution network as further load is restored	• All undamaged transmission network is energised • The distribution network is all progressively energised
Load restoration	• Initially only a small portion of the consumer load is restored, primarily only to stabilise the system voltage	• More consumer load is energised as the available generation increases and the network is progressively	• All consumer load is progressively restored, unless prevented by network damage

	Stage 1 - restart system	Stage 2 – restore generation	Stage 3 – restore load
	and frequency • Priority given to sensitive loads, where practical	restored	

The restoration process described in section 2.1.5 is shown graphically in Figure 2.1.

Figure 2.1 Restoration Stages and the Standard



The figure shows that the first stage of the restoration process is to restart selected generating units. At the end of this first stage sufficient transmission network and generator capacity would be available to be able to restart all the other generating units required to meet the consumer load later in the restoration process. As discussed further in section 2.1.6, the Standard is only concerned with the first stage of the restoration process where SRAS begins the process of restarting other generators. After Stage 1 other factors more strongly influence the restoration process.

The actual restoration process that is followed will depend on the characteristics of the affected part of the power system and the specific circumstances that have occurred, including the extent of equipment damage associated with the major supply disruption. As discussed in section 2.2.2AEMO is required to prepare the System Restart Plan for managing and coordinating system restoration activities during any major supply disruption, while Network Service Providers and Generators are required to develop local black system procedures to be initiated during a major supply disruption.

The characteristics of the power system that can affect the restoration process include types of generation in the power system, the physical distances between the generating units and the load centres, as well as the degree of interconnection with other regions.

For example, a power system that contains predominantly hydro generating units or gas turbines can generally be restarted more quickly than a system with mainly large thermal units, particularly if these units are not restarted within a few hours of tripping.[28] Restoration speeds can also be increased if there are relatively short electrical paths between the SRAS sources, other large generating units to be restarted and to the consumer loads that are being restored.

Some of the other circumstances that could affect the speed and reliability of the restoration process include:

- the extent of the power system that is in a black system condition;
- the presence of adverse weather or bush-fire conditions that could risk the security the system when the restoration is occuring;
- the extent of equipment damage that could reduce the options available during the restoration;[29]
- whether the system can be restarted from a neighbouring network, for example using an interconnector to a neighbouring unaffected region;
- if any pockets of operating load and generation exist within the affected network, including any power stations that have successfully tripped to house load; and
- which SRAS sources are available within the affected network.

The two factors in the process of system restoration particularly likely to influence the restoration of supply to consumers are:

- the restoration of the network and consumer load;
- time limits for avoiding a prolonged restoration process.

Restoration of the network and consumer load

Restoration of the network and the consumer load is a slow process, especially at the beginning when the restarting power system is small. Each network element needs to be energised individually and consumer load needs to be re-connected in small blocks in order to deliver a stable restoration of the power system.

In effect, this means that during a system restoration, load is restored primarily for the purposes of balancing the re-energisation of transmission lines and new generation, rather than for the purposes of restoring supply to consumers.[30] In practice this means

28 Russel Skelton and Associates, Submission to the Issues Paper. p.26.

29 Black system conditions would represent a large departure from the normal operation of the network, potentially including some degree of unforeseeable damage to, or unavailability of, transmission and generation assets. As a consequence, it is impossible to plan for all possible eventualities in advance.

30 This is necessary because energising a transmission or distribution line, or an underground cable, generates reactive power that causes a step increase in the network voltage, with the size of the step dependent on the length of line or cable being re-energised. In addition, connecting a large transformer can cause a drop in the network voltage for up to several seconds, with the size of the voltage drop depending on the relative size of the transformer. The re-connection of a block of consumer load can also cause a drop in the network voltage due to the increase power flows in the network elements supplying the loads. In addition, connecting a block of load can also cause the system frequency to drop as the load increases on the generating units that are operating at that time.

the size of the blocks of load that can be connected need to be limited to about 5 MW[31] to maintain the voltage and frequency stability of the network as it is being restored.

The step changes in the voltage and system frequency due to re-connection of network elements or blocks of consumer load are particularly pronounced when only a small number of generating units are operating and only a few network elements are connected. This means that particular care must be taken in terms of reconnecting load in the earliest stages of a power system restoration.

Prolonged restoration

Another key issue is that the process of power system restoration can become significantly harder once certain time thresholds are passed.

For example, if supply is not restored to key substation within about 10 hours the restoration process will become significantly more difficult because the operation of the control and protection systems in the transmission and distribution substations relies on local battery supplies. If there are no backup generators (such as diesel) then the supply batteries can become flat preventing the operation of the protection systems, as well as preventing remote operation of the control systems. This would mean that switching operation at the substation would need to be performed manually by technical staff at the substation, which introduces significant delays as these substations are generally unmanned. In addition, there would be long travelling times for staff to get to the substations[32] and all switching operations at the substations would need to be coordinated using radio based communications as normal telephone communications would also be unavailable.

2.1.6 The System Restart Standard

To ensure that sufficient SRAS is available in the NEM, the Rules require the Panel to determine the Standard. As discussed in section 2.2, the Standard is determined by the Panel through a review process and becomes a procurement target for AEMO when it procures SRAS.

While the ultimate goal of the restoration process is to restore consumer load, the Rules defines the system restart standard in terms of maximum time required to restore supply to a given level.[33] This is because the purpose of the Standard is to ensure an appropriate level of SRAS capability is available so that the system can be restarted. Once the system is restarted then there would be sufficient generation capacity available to supply the auxiliary loads of the other units and continue the restoration process.

In addition to a maximum time required to restore supply to a given level, the Standard also includes an aggregate required reliability for the SRAS in each electrical

31 The 5 MW value is based on discussions with AEMO and network service providers.

32 Driving would be expected to take significantly longer during a major supply disruption than under normal conditions. In urban areas the traffic may rapidly become congested as commuters make alternative arrangements to get home at the same time as traffic lights are likely to be no longer operating. In rural areas delays are likely due to the long distances between the TNSP and DNSP depots and their substations.

33 Clause 8.8.3(aa)(2) of the Rules.

sub-network.[34] To meet the Standard, AEMO is required to consider the reliability of the individual SRAS sources it procures and whether in combination they provide a sufficiently high likelihood of meeting the required level of supply within the maximum time specified in the Standard.

The Standard also provides guidelines to AEMO on how it is to treat diversity and any strategic locations required for SRAS.[35]

2.1.7 Electrical sub-networks

It is important that the SRAS procured in anticipation of a possible major supply disruption are reasonably evenly distributed throughout the NEM. This is to ensure that:

- the supply to all major power stations can be reasonably quickly restored so that they can be restarted without significant delays; and
- each major part of the power system contains at least one SRAS source so that part of the system can be restarted independently, should it be separated from the remainder of the system.

These two objectives are achieved in the NEM by sub-dividing the power system into electrical sub-networks for the purposes of acquiring SRAS and developing operational plans for managing major supply disruptions. AEMO is responsible for determining the boundaries of the electrical sub-networks,[36] using criteria specified in the Standard by the Panel.[37]

Currently AEMO has determined that there are six electrical sub-networks.[38] These are Queensland North, Queensland South, New South Wales, Victoria, South Australia and Tasmania. With the exception of Queensland, the sub-networks follow the NEM region boundaries.[39]

The Standard applies in all regions in the NEM but can vary between the different electrical sub-networks.[40] This may be done to better reflect the particular technical system limitations or requirements or the economic circumstances that apply within an electrical sub-network.

The Standard provides guidelines to AEMO on how it is to determine the boundaries for the electrical sub-networks.[41] This includes guidance to the determination of the appropriate number of electrical sub-networks and the characteristics required of an electrical sub-network. Such characteristics could include the amount of generation or

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34 Clause 8.8.3(aa)(3) of the Rules.

35 Clause 8.8.3(aa)(7) of the Rules.

36 Clause 3.11.8 of the Rules

37 Clause 8.8.3(aa)(6)

38 AEMO, Boundaries of electrical sub-networks, 27 June 2014

39 The Queensland region is divided into two sub-networks with the boundary being on the South Pine - Palmwoods and Halys - Calvale transmission lines.

40 Clause 8.8.3(aa)(4) of the Rules.

41 Clause 8.8.3(aa)(6) of the Rules.

load within an electrical sub-network and the electrical distance between generation centres.

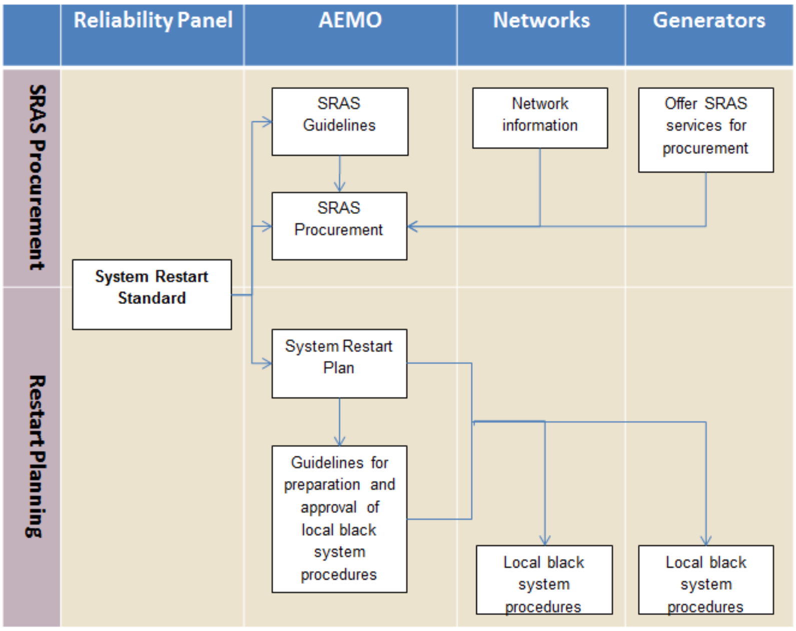
2.2 Governance Arrangements

This section provides an overview of the overarching policy framework for preparing for a major supply disruption under the Rules, including statutory roles and responsibilities of the Reliability Panel, AEMO, Network Service Providers and Generators. Further detail is provided in Appendix E.

2.2.1 Preparing for a Major Supply Disruption

The Rules place obligations on various parties to establish the capability to be able to restart the power system following a major supply disruption, including key roles for the Panel, AEMO, networks, and generators. A graphical representation of these responsibilities is laid out in Figure 2.2.

Figure 2.2 Responsibilities of parties in preparing for a major supply disruption



Reliability Panel

The Panel is responsible for reviewing and determining the Standard in accordance with the SRAS Objective, which is discussed in Chapter 3. The other requirements under the Rules for the Standard are contained Appendix D.

AEMO

AEMO's responsibilities under the Rules include procuring SRAS to meet the Standard at the lowest cost[42] and developing a confidential System Restart Plan that is consistent with the Standard.[43] AEMO is also responsible for recovering the costs of SRAS.[44]

42 Clause 3.11.7(a1) of the Rules

43 Clause 4.8.12(c) of the Rules

In addition AEMO is responsible for developing the SRAS Guideline[45] and assessing the ability of procured SRAS to meet the Standard through detailed testing and power system modelling. This includes consulting with the relevant TNSPs and DNSPs to identify and resolve issues in relation to the capability of the proposed SRAS.[46]

Networks

The networks are responsible for providing AEMO with information to facilitate the procurement of SRAS.[47] In addition, they must prepare and submit to AEMO local black system procedures on the actions that would be taken in the eventuality of a major supply disruption.[48]

Generators

Generators with the relevant specialised equipment are able to offer to provide SRAS. Generators that receive payment for the provision of SRAS are required to maintain their restart capacity and undertake regular testing as set out in the guidelines.

Generators must prepare and submit to AEMO local black system procedures on the actions that would be taken in the eventuality of a major supply disruption.[49]

2.2.2 Roles and responsibilities during a major supply disruption

This section describes the specific roles and responsibilities of parties during the restoration of the power system following a black system condition associated with a major supply disruption. These parties include AEMO, TNSPs, Generators and the Jurisdictional System Security Coordinators (JSSCs).[50]

AEMO

AEMO has overall responsibility for coordinating the restart and restoration process. AEMO will first make an assessment of the extent of the major supply disruption and whether there is a black system condition, including requesting status information on availability and damage from the relevant generators and TNSP.

AEMO will then determine the fastest and most reliable process to restart the part of the network affected by black system condition, including whether:

- the network can be restarted from a neighbouring electrical sub-network or from a generating unit that has remained operating; or
- the restoration process would be faster if one or more of the procured SRAS sources were to be used.

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44 Clause 3.15.6A(c2) of the Rules requires AEMO to recover the costs from those regions that benefit from the SRAS service, with the costs split equally between generators and market customers.

45 Clause 3.11.7(c) of the Rules

46 Clause 3.11.7(b) of the Rules

47 Clause 3.11.9(I) of the Rules

48 Clause 4.8.12(d) of the Rules.

49 Clause 4.8.12(d) of the Rules.

50 The JSSC is appointed by the Minister under the National Electricity Law. Under the NER, AEMO must coordinate with the JSSC in relation to a number of power system security matters.

AEMO will then coordinate the rebuilding of the transmission network following its System Restart Plan. AEMO, in coordination with the TNSP, will need to ensure that no elements are overload and the voltage stays within acceptable limits when a network element, load or generating unit is reconnected.

While AEMO would aim to restore the power system to the requirements of the Standard following a major supply disruption, it is not accountable in an operational sense if the time and level of restoration specified in the Standard is not met. That is, the Standard sets a target for procurement of SRAS based on restoration modelling and is not an operational standard that applies for the specific circumstances of a real black system condition.

TNSPs and DNSPs

An affected TNSP or DNSP will need to assess the status of its network following a major supply disruption. The re-energisation[51] of any transmission network elements will need to be authorised by AEMO to reduce the risk of a collapse of the power system being restored.

The TNSPs will also need to liaise with any large transmission connected loads and the associated DNSPs to prepare blocks of load to be connected as the network is restarted and restored. Reconnecting any load would need to be authorised by AEMO to ensure that the system frequency and the voltage profile remains within appropriate limits.

The DNSPs will need to make the necessary preparation to restore supply to small blocks of load, as required.

Generators

An affected generator will need to assess the status of its generating units after a major supply disruption. In particular, the generator will need to determine which of its generating units are still operating and assess if any of its units are damaged. The generator will need to stabilise the operation of any of its generating units, to the extent possible.

The generator will also need to prepare its units for restarting, particularly those that have been procured under a SRAS contract. The generator will then need to be ready to respond to AEMO instructions and directions in relation to its generating units.

Jurisdictional System Security Coordinator

AEMO, the TNSP and the DNSPs must coordinate the restoration process with the relevant JSSC.

2.3 Past reviews of the System Restart Standard and related processes

In 2006, AEMO (then NEMCO) created an interim System Restart Standard in response to the AEMC's system restart ancillary service arrangements rule change. The interim

51 Re-energisation refers to the reconnection of a network element that has been de-energised as a result of the major supply disruption. Energisation is defined in chapter 10 of the Rules as "The act of operation of switching equipment or the start-up of a generating unit, which results in there being a non-zero voltage beyond a connection point or part of the transmission and distribution network."

standard was reviewed by the Reliability Panel in 2012, with only minor modifications being made to create the current Standard.

In 2013 AEMO reviewed the SRAS guidelines and made a number of changes and clarifications including revision of the sub-network boundaries and clarification of SRAS applicability and reliability. These rule changes and review are discussed in further detail in Appendix F.

On 2 April 2015 the AEMC published a final determination on a rule change relating to SRAS.[52] In its final determination the AEMC made a number of changes to the governance, procurement and cost recovery frameworks for SRAS. These changes were designed to improve the function of the Standard and to provide clarity regarding the roles and responsibilities of AEMO and the Reliability Panel.

Changes to clarify the roles and objectives of both AEMO and the Reliability Panel included:

- AEMO's objective is to procure sufficient SRAS to meet the Standard at the lowest cost. Importantly, AEMO is no longer required to meet the broader SRAS Objective. This means that AEMO does not have discretion to procure any more SRAS than is required to meet the Standard defined by the Panel.
- The SRAS Objective was amended to remove any specific requirement for the Reliability Panel to determine the Reliability Standard through a cost benefit analysis. While the Panel retains the discretion to undertake any analysis as it sees fit, the Commission sought to clarify that the Panel was not under any obligation to determine the Standard in this manner.[53]

Changes made to the requirements specified in the Rules for the System Restart Standard included:

- the System Restart Standard must specify that procurement of SRAS for each sub-network takes place under the assumption that supply (other than that provided under a SRAS agreement acquired by AEMO for that electrical sub-network) is not available from any neighbouring electrical sub-network. In effect, this requires AEMO to procure SRAS on the basis of restoring each electrical sub-network independently, with no supply available from any neighbouring electrical sub-network;
- the Standard must include an aggregate required reliability for SRAS in each sub-network, allowing AEMO to procure multiple SRAS with varying reliability levels, in order to meet a single aggregate reliability requirement in each electrical sub-network;
- the definitions of primary and secondary restart services are removed from the Rules and the Panel is no longer required to specify guidelines for primary and secondary services; and

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52 The rule change process combined two proposals from: the National Generators Forum, AGL, Alinta Energy, Energy Brix, GDF Suez, Intergen, Origin Energy (the Group of Generators), received 11 November 2013; and AEMO, received 20 December 2013.

53 Section 3 covers the assessment framework for the 2016 Review of the Standard

- the standard must specify that SRAS can only be acquired by AEMO for one electrical sub-network at any one time.

2.4 The System Restart Standard as a procurement standard

The Standard is currently set out as a procurement target for AEMO. Therefore, in meeting the Standard, AEMO must procure sufficient SRAS to meet the requirements of the Standard. While AEMO would aim to restore the power system to the requirements of the Standard following a major supply disruption, it is not accountable in an operational sense if the time and level of restoration specified in the Standard is not met.

In 2012 the Panel clarified that this requirement is a procurement standard and not an operational standard.[54] As part of the SRAS rule change, the Commission determined that the Standard should remain only a procurement standard.

Section 3.11.7 of the NER describes the SRAS Procurement Objective that AEMO must comply with and how this relates to the Standard.

"(a1) AEMO must use reasonable endeavours to acquire system restart ancillary services to meet the system restart standard at the lowest cost (the SRAS Procurement Objective)"

54 AEMC, System Restart Ancillary Services Rule Change, 2015, p.48.

3 Assessment Framework

This chapter sets out the assessment framework that the Panel has considered when undertaking the review of the Standard.

3.1 SRAS Objective and National Electricity Objective

The Panel must review and determine the Standard in accordance with the SRAS Objective, as set out below:[55]

> "The objective for *system restart ancillary services* is to minimise the expected costs of a *major supply disruption*, to the extent appropriate having regard to the *national electricity objective*."

The SRAS Objective requires a Standard that minimises the total ongoing cost of a major supply disruption. This total ongoing cost would be equal to the cost of providing SRAS sources plus the cumulative costs to society of a prolonged disruption to the supply.

When considering the SRAS Objective, the Panel needs to have regard to the National Electricity Objective (NEO), which is:[56]

> "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:
>
> (a) price, quality, safety, reliability and security of supply of electricity; and
>
> (b) the reliability, safety and security of the national electricity system."

The requirement for the Panel to have regard to the NEO was added to the SRAS Objective by the Commission and involves the Panel considering various economic and social factors when determining the Standard, including the trade-offs that exist between the cost of procuring SRAS against the short term costs of supply loss and the longer term costs of economic disruption.[57]

3.2 The Panel's consideration of the SRAS Objective and NEO

The Panel considers that the relevant aspects of the NEO for this review are more efficient investment and operation of electricity services, particularly with respect to the price of SRAS and the reliability of the national electricity system, in particular the reliability of the restoration from a major supply disruption.

In determining the Draft Standard the Panel has undertaken an assessment of the economically optimal level of SRAS taking into account the technical attributes of the power system. This is where the probability weighted marginal benefit of procuring an additional SRAS source is approximately equal to the marginal cost of procuring that

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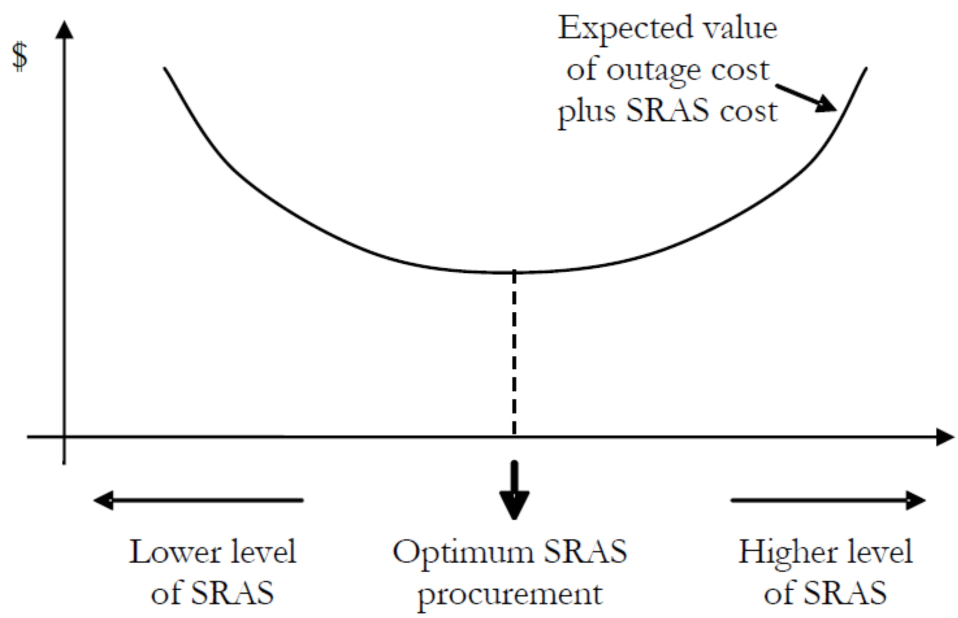
55 Clause 8.8.3(aa)(1) of the Rules.

56 NEL, s. 7.

57 AEMC Rule Determination – System Restart Ancillary Services, April 2015, p.iii.

SRAS source. Figure 3.1 shows this trade-off graphically where the bottom of the curve corresponds to a level of SRAS procurement that minimises the total costs.

Figure 3.1 Optimum level of SRAS Procurement[58]



The Panel considers that there is a range of approaches that it could use to determine the Standard that meets the SRAS Objective. In addition to an analysis of the marginal cost and marginal benefit of each additional SRAS source, the Panel has also considered a risk management approach to inform its determination of the Standard. The goal of the economic assessment is to determine the "economically optimal" expenditure on SRAS given the likelihood of a black system event, while a "risk management approach" seeks to provide a high degree of certainty that the power system will be able to be restarted in the event of a region wide major supply disruption, within an acceptable time. These approaches are described in further detail in section 6.2.2

3.2.1 Factors considered by the Panel in the Review

In determining the Draft Standard, the Panel has considered the following factors.

The physical limitations of the power system

The rate at which the supply in an electrical sub-network can be restored depends on the technical characteristics of generation and transmission network elements in that sub-network. Therefore, the determination of the Draft Standard at a level that is both achievable and efficient level requires an understanding of these technical characteristics, particularly the generating units that provide SRAS.

Minimising the expected cost of a major supply disruption

The expected cost of a major supply disruption includes the likely impact on the loss of supply on consumers and the cost of procuring SRAS to restart the generation in the electrical sub-network. This is discussed further in Chapter 5.

58 Firecone, Review for AEMC of the Proposed NEMMCO Rule for System Restart Ancillary Services, 2005, p. 6.

Expected social costs of a major supply disruption

The cost of a major supply disruption needs to consider both the direct impacts of a loss of supply on individual consumers and other indirect social costs. Examples of social costs could include the transport congestion that would result from the absence of traffic lights, the loss of telecommunications networks and the impacts on hospitals. This is discussed further in Chapter 5 and in the advice from Deloitte Access Economics.

Specific economic circumstances in an electrical sub-network

The economic cost of a major supply disruption, and hence the efficient level of SRAS to restart the electrical sub-network, depends on the specific characteristics of the affected consumers. This is discussed further in Chapter 5 and in the advice from Deloitte Access Economics.

Consultation with jurisdictional governments

The Panel consulted with the jurisdictional governments to identify any specific issues or matters that they considered particularly important to the determination of the Draft Standard for their electrical sub-networks.

Reliability of potential SRAS sources

The procurement of an additional SRAS source with a high reliability would be expected to improve the restoration of the sub-network more that the procurement of a source that is less reliable. Therefore, the assessment of the Draft Standard has considered the expected reliability of the potential SRAS sources that are available to each electrical sub-network

Cost of procuring additional SRAS

The expected price that the market needs to pay to procure addition SRAS will influence the determination of the economically most efficient level of the Draft Standard. Therefore, as discussed below, the Panel asked AEMO to provide the AEMC staff responsible for providing the Reliability Panel with secretariat services with advice on the recent offers it has received from potential SRAS providers.

Restoration of load

The Panel understands that while the primary goal of the Standard is to provide a target for AEMO to procure SRAS to enable the restoration of the generation and transmission necessary to support a functional power system, the restoration of supply to consumers is the end goal following a major supply disruption. In formulating the Draft Standard, the Panel has considered the timings and expectations for the restoration of load on a regional basis.

3.2.2 Specialist advice

In determining the Draft Standard, the Panel also considered relevant specialist advice, including a comparison of international experience related to black start restoration and technical advice on the NEM power system.

Technical advice on the Power System

To determine an efficient level for the Draft Standard it is necessary for the Panel to understand the impact of different levels of SRAS on the restoration process following a major supply disruption. This will allow the economic benefits to consumers of different levels of SRAS procurement to be quantified and, when compared to the cost of procuring SRAS, an efficient level for the Draft Standard can be determined. However, the impact of SRAS on the restoration process varies significantly for each of the electrical sub-networks in the NEM due to the differing technical characteristics of the SRAS sources, the other generation sources and the transmission network.

In addition, the point in the restoration process where the affected electrical sub-network is considered to have been restarted will also vary between the sub-networks. This point is when all the generation within the affected sub-network has either been restarted or has supply to its auxiliary loads and is in the process of restarting if required[59] At this level of supply it is possible to restore the remainder of the generation and progressively re-connect further load. Beyond this point in the restoration process the level of supply is such that the SRAS sources used to restart the system generally provide only a minimal ongoing benefit to the restoration. Therefore the Draft Standard will also need to reflect the time and level of supply to restart the electrical sub-network that is achievable taking into consideration the technical characteristic of the sub-network.

To understand the technical characteristics of the power systems for each of the electrical sub-networks the Panel sought technical advice from AEMO. This advice has been used by the Panel to determine set-points for the Draft Standard that includes the following components for each electrical sub-network:

- a maximum time to restore supply to a given level;
- the required level of supply; and
- an aggregate reliability for the set-point.

The technical advice from AEMO can be divided into advice in relation to time and level components of the Draft Standard, and advice in relation to SRAS reliability.

In addition, the Panel consulted with the JSSCs to identify any regionally specific power system characteristics that it should consider.

International comparison of blackouts and restoration

A review of other regulatory arrangements from other power systems would be informative to allow consideration of ‘best practice internationally, as well as understanding whether there have been useful lessons from the recent blackouts in other power systems.

3.2.3 Economic Assessment

As noted above, to determine an efficient level for the Draft Standard, it was necessary for the Panel to consider the economic benefits to consumers of different levels of SRAS procurement when compared to the cost of procuring SRAS in addition to the differing technical characteristics of the SRAS sources, the other generation and the transmission network.

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59 The point when all the generation has either restarted or is restarting is referred to as the end of stage 1 of the restoration in Chapter 2.

It is difficult to perform an economic assessment to accurately determine an efficient appropriate level for the Draft Standard. This is because there are so many uncertainties with respect to:

- the time taken to restore supply to consumers from different SRAS sources;
- the time taken to re-connect consumers once supply is restored;
- the reliability of the procured SRAS sources and the potential availability of alternative means of restarting the power system;
- risks to the restoration process due to damage to generation or network equipment;
- the range of values that different customers place on a supply interruption, including wider impacts on society;
- the time of day and day of week that the major supply disruption
- how often major supply disruptions occur and SRAS is required to restart an electrical sub-network; and
- the extent to which stakeholders are risk adverse and wish to procure SRAS above or below the economically efficient level.

While it is difficult to perform such an economic assessment, there is broad agreement that the inclusion of an “economic trade off” would provide an improved basis for the Draft Standard and provide stakeholders with increased confidence that the economically efficient level of SRAS procurement that is consistent with the NEO will be maintained.

Russel Skelton and Associates, representing the views of some generators and major energy users, consider that the current Standard has been set on a technical basis but it should take into account the economic trade-off between the incremental benefits of improving the expected time for restoration of load compared to the incremental costs of achieving this.[60] Similarly AEMO noted in its submission that “despite the difficulties with quantification, an assessment within a logical, quasi-probabilistic framework could be useful, especially in assessing relative benefits between alternatives being considered.”[61]

The Panel agrees and has commissioned an economic assessment to inform its determination of the Draft Standard. This assessment considers the trade-off between the cost of procuring amounts of SRAS and the expected impact on the cost of a major supply disruption, weighted with an estimate of the probability of such a major supply disruption occurring. This assessment uses the technical advice for each electrical sub-network described in section 4.3 and provides a more precise description of the relative value of different levels of SRAS procurement.

The economic assessment was performed for each of the current electric sub-networks in the NEM and considered the:

- incremental direct, indirect and social costs cost of outage (in $/MWh);

60 Russ Skelton & Associates, Submission to the Issues Paper, pp. 2, 31 and 42.

61 AEMO, Submission to the Issues Paper, pp. 3-4.

- probability of a major supply disruption requiring SRAS;
- expected quantity of unserved energy likely to occur during such a major supply disruption;
- expected length of outage; and
- aggregate reliability of the SRAS portfolio.

The fundamental goal of the economic analysis is to highlight the economically optimal level of SRAS expenditure in accordance with the SRAS Objective and the available information. However, it has previously been recognised that there is a high degree of uncertainty surrounding the inputs to this economic assessment as described in the 2015 SRAS Rule change: [62]

> "Undertaking a full cost benefit analysis requires the quantification of key variables, including the probability of certain events occurring, and the costs associated with those events. However, the Commission considers that it is not possible to estimate accurate values for these variables with regard to a potential major supply disruption. The probability of a major supply disruption occurring is inherently uncertain. There is a very large number of unpredictable variables involved in the triggering and propagation of a cascading failure. The extent of these unpredictable variables makes any kind of meaningful risk assessment impossible, given the number of simplifying assumptions that would be needed. This means that it is very difficult, and possibly misleading, to assign a probability to a region wide, multi-region or a NEM-wide black system event, for the purposes of undertaking a cost benefit analysis. Furthermore, the costs associated with a large scale major supply disruption are also extremely difficult to quantify. These costs are not likely to be limited to the immediate interruption of economic capacity, but are likely to have prolonged consequential effects. These costs will also vary substantially between different users, as well as across time."

Given this uncertainty, a key output of the economic assessment of SRAS is the sensitivity analysis which generates a range of potential SRAS procurement levels based on the expected levels of uncertainty associated with each of the input variables.

Further description of the economic assessment, including the results of the assessment, is discussed in Chapter 5 and in the Economic Assessment of SRAS Report.[63]

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62 AEMC, System Restart Ancillary Services Rule Change, Final Determination, 2015, pp. 57-58.

63 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, 2016.

4 Specialist Advice

This chapter provides an overview of the specialist advice that the Panel took into account in determining the Standard. This advice includes:

- an international comparison of blackouts and restoration, including any lessons for the determination of the Draft Standard for the NEM; and
- advice from AEMO on the technical characteristics of the potential SRAS sources, generation and network in each electrical sub-network, including the viable restoration paths and expected reliability.
- an overview of the approach to the economic assessment used to inform the Panel's assessment of the Draft Standard.

4.1 International Comparison of Major Blackouts and Restoration

All electrical power systems need to include some form of black start capability to mitigate against the risk of a major supply disruption. In each case, different governance and regulatory arrangements operate in different power systems and in each case the provision of black start capability will have been considered. In addition, there have been several major supply disruptions in other electrical power systems recently and it is likely that some valuable lessons could have been learned from the process that was followed to restart the power system and re-connect supply to consumers.

To determine whether there have been useful lessons from the recent blackouts in other power systems, or the regulatory arrangements from other power systems could assist the Panel to determine the Draft Standard, the Commission engaged DGA Consulting on behalf of the Panel to undertake an International Comparison of Major Blackouts and Restoration.[64] This document was published on the AEMC's website on 5 May 2016 and reported on two key tasks:

- Task 1 - An international comparison of major blackouts; and
- Task 2 - An international review of regulatory arrangements to prevent or mitigate such outages including restoration.

The final DGA report summarised the characteristics of five major blackouts that have occurred internationally along with a summary of the system restart policy settings in five major international jurisdictions, based on similarity to Australia’s NEM.

Table 4.1 below outlines the major supply disruptions considered in the DGA Report.

64 DGA Consulting, 2016, International Comparison of Major Blackouts and Restoration

Table 4.1 Major supply disruptions considered by DGA

Year	Location	Peak Power Loss	Time to Restore Generation and Transmission[65]
2003	Eastern United States	61,800MW	6 hrs
2003	Italy	35,000MW	3 hrs
2008	Hawaii, USA	1,000MW	5 hrs
2011	San Diego, USA	8,000MW	N/A[66]
2013	Sarawak, Malaysia	1,600MW	3 hrs

The conclusions from this study relating to these outages and restoration are set out in box 4.1.

Box 4.1 International Comparison - Conclusions related to Blackouts and Restoration

1. Outages

a. Transmission versus generation causes—the blackouts reviewed in Task 1 were all initiated by unexpected transmission events. A transmission failure leads to a very rapid increase in loading or decline in voltages leading to a series of other equipment trips. The result is a sudden, usually large, uncontrolled customer outage. In contrast, with a generation shortage there is usually at least several hours of advance warning of an impending shortage. These result in controlled rotating customer outages.

b. Not at peak load—none of the events occurred under peak load conditions. It is common to study peak conditions, but the system is often more vulnerable during off-peak seasons when generating units are not dispatched or on maintenance. There are also usually transmission maintenance outages that have led to errors that cause outages.

c. In all these blackouts there were multiple contingencies, beyond normal operating and planning criteria.

2. Restoration

a. Situational awareness is an important first step. In some cases, lack of awareness was an important factor that delayed restoration.

b. Where interconnections were available (not Hawaii or Sarawak) operators used

65 This is equivalent to NEM stage 1 (Gmin). The stages of the restoration process are defined in section 2.1.5 and Gmin is defined in section 4.3.1 as the minimum required online generation capacity to support the ongoing restoration of the power system.

66 System Restored by interconnections with neighbouring networks

them early in restoring the system.

c. There are usually electrical islands that maintain service through the blackout.

d. With widespread outages:

- Usually some equipment fails beyond the initiating causes; and
- Some setbacks occur during restoration, usually due to voltage control problems.

The DGA Report also described in the black start policy settings for the following jurisdictions:

- PJM, United States;
- ERCOT, United States;
- Italy;
- Ireland; and
- South Africa.

The conclusions from this study relating to review of international black start policy settings are shown in the box 4.2.

Box 4.2 International Comparison - Conclusions related to Black Start Policy Settings

1. Energising parts of the system within 3-4 hours is common, but fully restoring the system may take 12 hours or more.
2. None of the systems require a percentage of load to be ready to be restored. Some have specific critical loads, usually nuclear power station auxiliary supplies that need to be restored first and to be energised in 3-4 hours.
3. Multiple black-start resources should be available, though they can be in neighbouring networks.
4. There are few specific requirements for voltage control, though, obviously, voltages must be within safe limits
5. Black-start studies are usually conducted for normal conditions
6. None of the systems reviewed here, consider fuel diversity in identifying black-start generation.

4.2 Technical Advice

The Panel is required to consider advice from AEMO when undertaking the review of the Draft Standard.[67] In keeping with this requirement, the Panel sought technical advice from AEMO on the technical characteristics of each of the electrical sub-networks, including the effectiveness of potential restart sources and the viable paths for restoring supply in the sub-networks.

67 Clause 8.8.1(a)(1a) of the Rules

4.2.1 Time and level of the Draft Standard

The technical advice provided by AEMO was used to define the boundary conditions for the time and level elements of the Draft Standard, this advice includes:

- the minimum required online generation capacity to support the ongoing restoration of the power system (G_{min});
- the minimum reasonably achievable restoration time (T_{min}) for restoring the available generation to G_{min} in each sub-network; and
- the maximum threshold restoration time (T_{max}), beyond which a prolonged power system restart is likely.

Minimum generation level for ongoing power system restoration (G_{min})

The minimum generation level or G_{min} is a measure of the threshold for generation and transmission network restoration, beyond which the auxiliary loads of all major power stations can be energised and the ongoing restoration of the power system can proceed without the need for SRAS and while maintaining the power system in a secure operating state.

Minimum reasonably achievable restoration time (T_{min})

The minimum reasonably achievable restoration time (T_{min}) defines the fastest technically feasible time for restoring the power system up to the level where the available generation exceeds G_{min} in an electrical sub-network. This time is defined by the fastest feasible restoration path for a given electrical sub-network under the assumptions set out in the Standard,[68] given the existing generation and transmission elements in the power system.[69] This time is based on all the available SRAS operating correctly, such that a faster restoration cannot be expected with the existing power system elements.

Maximum threshold restoration time (T_{max})

The maximum restoration time (T_{max}) describes the longest period before which the system must be restarted to avoid a very prolonged restoration. A prolonged restoration is likely to occur as the control and protection systems at the transmission substations rely on emergency supplies (batteries and sometimes backup diesel generator) that only operate for a number of hours without supply from the transmission network. Local manual operations of the substation switchgear would be required if the emergency power supplies were unavailable, increasing the complexity and difficulty of undertaking the required switching operations. Therefore, it is important to complete the first stage of the restoration process while the emergency supplies are available and the Standard should aim to complete this stage before T_{max}.

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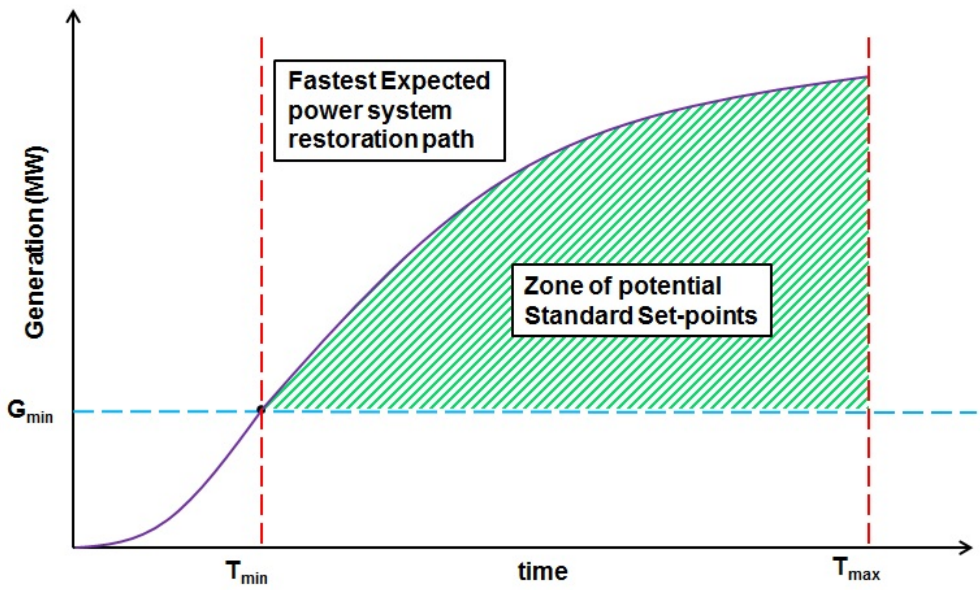
68 NER cl 8.8.3 (aa)(2) of the Rules, " under the assumption that supply (other than that provided under a *system restart ancillary* services agreement acquired by AEMO for that *electrical sub-network*) is not available from any neighbouring *electrical sub-network*"

69 Under the assumption that the transmission power system is intact which is the currently applied by AEMO when assessing the capacity of procure SRAS to restore each sub-network. NER cl. 3.11.7(d)(3) gives AEMO the discretion to make an assumption "regarding the state of transmission elements during a major supply disruption".

Thus T_{max} is treated as a maximum time limit for restoration of generation and transmission above the G_{min} threshold.

Figure 4.1 displays the generic power system attributes and provides a representation for how these attributes combine to provide boundaries for the "zone of potential SRAS Set-points".

Figure 4.1 Boundary Conditions for Time and Level



The Standard will define a set-point (or set-points) to enable SRAS to be procured with a goal to restart generation and energise transmission in excess of G_{min} within a time between T_{min} and T_{max}.

Table 4.2 displays the sub-network specific values for G_{min}, T_{min} and T_{max} based on information provided by AEMO and used as technical boundaries in this review.

Table 4.2 Power System Characteristics

Electrical Sub-Network	G_{min} (MW)	T_{min} (hours)	T_{max} (hours)
Queensland North	825	3	10
Queensland South	825	1.5	10
New South Wales	1500	1	10
Victoria	1100	1.5	10
South Australia	330	1	10
Tasmania	300	1	10

4.2.2 SRAS aggregate required reliability

The Draft Standard set-points for each of the electrical sub-networks also include an aggregate required reliability.[70] The aggregate required reliability represents the likelihood that the combined procured SRAS for a given electrical sub-network should be able to restore supply to the level requirement within the specified time, based on the combined reliability of each of the SRAS sources. This requirement was added to the Standard by the Commission in 2015 to increase AEMO's flexibility when procuring SRAS.[71]

In relation to the reliability of the potential SRAS sources in the NEM, the Panel sought advice from AEMO on its current approach for assessing the reliability of potential SRAS sources, as well as the reliability of specific restart technologies, such as TTHL.[72]

70 Clause 8.8.3(aa)(3) of the Rules.

71 The aggregate reliability component of the Standard was added as part of the AEMC's SRAS rule change, published in April 2015.

72 TTHL is a described in the National Generators Forum, submission to the 2015 SRAS Rule change as follows: "Immediately following a trip from the grid, TTHL schemes are designed to reduce the loading on a generating unit from supplying full capacity to supplying the auxiliary load of the power station. This process is performed by complex control systems that rapidly reduce fuel combustion, feed water and air systems in response to turbine output. TTHL enables large thermal stations to 'float' off-grid, where they are readily available to re-energise the network."

5 Overview of the Economic Assessment

This chapter describes the economic analysis that forms part of the Panel's review of the Standard. The chapter examines:

- the factors considered in the economic assessment;
- the economic assessment methodology; and
- the results of the economic assessment.

To inform its review of the Draft Standard, Deloitte Access Economics was engaged on behalf of the Panel to undertake an economic assessment of the economic benefits and costs of procuring different levels SRAS. This assessment describes the trade-offs between expenditure on SRAS and the benefit of a reduction to unserved energy in the event of a major supply disruption that requires SRAS to restart the power system. To achieve this, the assessment has quantified the marginal costs and marginal benefits of SRAS in the event of a major supply disruption that impacts an entire sub-network, based on the probability of such an outage occurring.

5.1 Economic Assessment Methodology

5.1.1 Benefits of SRAS based on load restoration times

The economic benefit of additional SRAS sources, or more reliable SRAS sources, is that the load that has been disrupted can be restored more reliably and potentially more rapidly depending on the location of the SRAS sources within the affected electrical sub-network. Conceptually the expected benefit from an improvement in the speed of the load restoration process is the product of:

- a technical estimate of the reduction in the unserved energy[73] that can be achieved when additional SRAS is able to speed up the process for restoring load, measured in MWh;
- an economic estimate of the value that consumers are expected to place on a reduction in the unserved energy, measured in $/MWh; and
- an estimate of the expected probability of a major supply disruption requiring SRAS occurring, measured in events/year.

The NEM electrical sub-networks can generally be restarted from multiple locations and a fastest reasonably practical restart can be achieved with multiple SRAS sources, spread out widely across the electrical sub-network. [74]For example, in New South Wales a SRAS source in the south and another in the Hunter Valley can effectively restart the New South Wales electrical sub-network, provided both sources operate correctly[75]If only a single SRAS source operates then the system restoration would be

73 In terms of assessing the value of SRAS; "unserved energy" is taken to be the amount of energy demanded, but not supplied, in a sub-network due to the major supply disruption.

74 Based on the generation restoration curves provided confidentially by AEMO.

75 The SRAS sources in the south of New South Wales would predominantly be used to restart the generating units in the Snowy Hydro scheme while a SRAS source in the Hunter Valley would be used to commence the process of restarting.

expected to be successful but would be slower compared to the expected restoration speed when both SRAS sources operate correctly. Procuring more than one SRAS source in each of these two locations within the electrical sub-network generally does not significantly improve the speed of the restoration process but does provide an additional level of redundancy, thus increasing the probability that the fastest reasonably practical restoration can be achieved when allowing for the reliability of the individual SRAS sources.

To assess the impact of a given set of SRAS sources it is necessary to consider the expected reliability of these SRAS sources and hence the potential combinations of these SRAS sources that could operate correctly. Each combination of operating SRAS sources would have:

- a probability of occurring based on the reliability of the individual SRAS sources; and
- a cost of the unserved energy that occurs during the expected time to restore the load.

5.1.2 Summary of approach used by Deloitte Access Economics

The economic assessment conducted by Deloitte Economics involves seven key steps, which have been conducted for each electrical sub-network:

1. Establish supply restoration pathways for each electrical sub-network, that is the different rates that the electrical system can be restarted within an electrical sub-network based on the level and combination of SRAS plants.
2. Quantifying unserved energy associated with each restoration pathway and quantifying the cost associated with this unserved energy.
3. Probability weighting the cost of unserved energy for each restoration pathway by incorporating the aggregate availability and reliability of each combination of SRAS plants.
4. Calculating the annualised marginal benefit of each combination of SRAS plants, by weighting the cost with the probability of a black system event.
5. Establishing the cost of procuring SRAS for each electrical sub-network.
6. Determining the level of SRAS where the probability weighted economic savings accrued from the addition of an SRAS unit are less than the additional cost.
7. Quantifying uncertainty in the results through a sensitivity analysis.

5.1.3 Approach to uncertainty used by Deloitte Access Economics

The Panel recognises the high level of uncertainty associated with the key variables that impact the economic assessment of SRAS. Therefore, Deloitte Access Economics was requested to pay attention to the impact of uncertainty in preparing the results of their cost-benefit analysis. A range of upper and lower sensitivity bounds was applied to each of the key variables used in the assessment.

The largest source of uncertainty is the estimate of the probability that a major supply disruption that impacts an entire sub-network is likely to occur. Such events are extremely rare but have severe social and economic impacts. Due to its rarity, and the limited historical outage data to inform a statistical analysis, the probability of such an event is inherently uncertain. To address the effect of this uncertainty on the economic assessment of SRAS, Deloitte Access Economics utilised multiple approaches based on extreme value theory, including a “power law” method and a Frechet, or inverse Weibull, distribution.[76] These methods attempt to provide a meaningful range of probabilities for these large supply disruptions based on the limited historical outage data available. A detailed description of the approach to uncertainty and the estimation of outage probability is presented in the Deloitte Report.

5.2 Factors considered in the economic assessment

This section describes the input data and assumptions used by Deloitte Access Economics for the economic assessment of SRAS. Further detail can be found in the Deloitte report.

5.2.1 Advice from AEMO

As noted in chapter 4, AEMO provided the AEMC staff responsible for providing the Reliability Panel with secretariat services with technical advice on the operation of SRAS in the NEM and confidential SRAS cost information.

The advice from AEMO for the economic assessment included:

- the price of SRAS offers from recent SRAS procurement processes performed by AEMO;
- the availability, estimated reliability and start-up performance for each SRAS source procured by AEMO; and
- curves for the restoration of generation capacity in each electrical sub-network for a range of different potential SRAS source.

This advice and cost information cannot be published as part of the Panel's review because it is confidential to AEMO's commercial contracting process.

In addition to the confidential advice described above, AEMO provided other information that was publicly available. This included:

- the AEMO report on the Value of Customer Reliability(VCR);[77] and
- advice on the major load shedding events during the period 1999 to 2015.

This technical advice and cost information is discussed further in section 4.2 and in the report on the economic assessment of SRAS by Deloitte Access Economics. The applicability of VCR as a measure of the value of unserved energy is discussed in Appendix B of the economic assessment of SRAS by Deloitte Access Economics.

76 Further details on the use of the Frechet, or inverse Weibull, distribution is provided on page 73 of report by Deloitte Access Economics titled, The economic assessment of System Restart Ancillary Services.

77 AEMO Value of Customer Reliability – Final Report, 28 November 2014

5.2.2 Assumptions and constraints used for the economic assessment of SRAS

When undertaking the economic assessment for the Panel, Deloitte Access Economics made a number of assumptions that are described in its report. These assumptions included:

- the economic assessment is based on a complete blackout of an entire electrical sub-network;
- the restarting of the electrical sub-network, and the restoration of generation and load, is performed assuming that supply from neighbouring sub-networks is not available;[78]
- there is sufficient redundancy in the transmission network such that there is no impact of transmission network damage on the restart or restoration processes;
- consumer load is assumed to be restored following the restoration of generation within an electrical sub-network with a 90 minute time lag;
- delays or failures of the generation and load restoration process after the end of stage 1 of the restoration process are ignored;
- each SRAS source has been assumed to have an availability of 95 per cent; and
- in order to estimate the costs on consumers of all SRAS sources failing on their initial attempt, it is assumed that when all SRAS sources initially fail to operate the power system in an electrical sub-network will be restarted to a minimum level of generation and transmission prior to T_{max}.[79]

These assumptions are discussed in further detail below.

Assessment of a complete blackout of an electrical sub-network

The economic assessment is based on a complete blackout of an electrical sub-network. This is the most severe condition that can affect the supply to an individual electrical sub-network. This is also consistent with the requirements of the rules.[80]

Supply from neighbouring electrical sub-networks is unavailable

The rules require that the Draft Standard specifies a standard for procuring SRAS under the assumption that supply is not available from any neighbouring electrical sub-networks.[81]

Transmission network damage

It has been assumed for the economic assessment that there is sufficient redundancy in the transmission network such that there is no impact of transmission network damage on the restart or restoration processes.

78 This is consistent with the requirements of clause 8.8.3(aa)(2) and the AEMO SRAS Guidelines.

79 T_{max} is defined in Chapter 3.

80 Clause 8.8.3(aa)(2) of the Rules.

81 Clause 8.8.3(aa)(2) of the rules.

The Panel acknowledges that it is quite possible that there could be material damage to the transmission network during the events that lead to a black system condition and associated major supply disruption. The impact of a single transmission network element is unlikely to have a material impact on the restarting of an electrical sub-network as the transmission networks generally have sufficient redundancy to provide alternative electrical paths to restart the generating units in the sub-network. In addition, it would be impractical to consider restarting an electrical sub-network with multiple network element failures, as there would always be a combination of network outages, no matter how unlikely, that would prevent the restart process. Therefore, setting a Draft Standard that catered for all possible multiple transmission network elements would be impractical and, if attempted, would lead to very high SRAS costs.

Consumer load is restored following a 90 minute lag of generation supply

The restoration of consumer load lags behind the restarting of SRAS and the restoration of the generation in the sub-network. The precise time to restore the load will depend on the rate at which the distribution network operators can set up their networks and reconnect blocks of load.

For the purposes of the economic analysis, it has been assumed that the consumer load is restored at the same rate as the generation but with a 90 minute time lag. To completely restore the entire load from an actual black system condition is likely to take significantly longer than this. However, the Panel considers that it is impractical to model the full load restoration process within the distribution networks for each SRAS scenario. Rather, the Panel considers that a 90 minute time lag is representative for the early stages of the restoration process and that applying a uniform assumption provides the consistency necessary to compare the different SRAS procurement and performance scenarios.

The economic assessment being undertaken is not sensitive to the precise rate at which consumer load is restored. Rather the economic assessment considers relative changes to the load restoration time for different levels of SRAS procurement, relative to the cost of procuring additional SRAS.

Delays or failures in stages 2 and 3 of the restoration process

As discussed is section 2.1.5, the main objective of the Draft Standard is to define the quantity of SRAS that is required to restart the electrical sub-network. This is specified as the amount of generation and transmission capability that should be available at the end of stage 1 of the restoration process. Therefore the economic assessment needs to consider the reliability of stage 1 of the restoration process, including one or more of the SRAS sources failing to operate. At the end of stage 1 of the restoration process the system has restarted and the SRAS sources are not necessarily required in stages 2 and 3. That is, the SRAS has done its job. Therefore, delays and failures in stages 2 & 3 of the restoration were not considered in the analysis as they do not impact the stage 1 restoration, which is the goal of SRAS and the System Restart Standard.

Subsequent delays and failures stages

In an actual restoration process there is a chance of a generation or network failure that introduces a subsequent delay to the load restoration process after the end of stage 1 of the restoration process. However, the possibility of such delays is not related to the procurement of SRAS, so such delays have been ignored in the economic assessment and are, therefore, not relevant to the setting of the Draft Standard.

Availability of SRAS sources

The assumption that each SRAS source has been assumed to have an availability of 95 per cent is based on advice from AEMO.[82]

Assumed electrical sub-network restart if SRAS fails

The economic assessment performed for the Panel considers the benefits on the time to restore load for different levels of SRAS procurement, and hence different levels of aggregate reliability. Additional SRAS sources improve the reliability of restoration process. However, no matter how much SRAS is procured there would be a residual possibility that all the SRAS sources fail to operate. In practice the failure of all available SRAS sources to operate would result in all possible ways to restart the sub-network being investigated including:

- repairs to contracted SRAS sources;
- the potential for other generating units to be able to restart; and
- re-establishment of the transmission network to allow supplies from a neighbouring sub-network.

In theory failure for all SRAS sources to operate would have a virtually infinite cost to consumers and would have a non-zero probability of occurring. This probability would be small in practice if the aggregate reliability of the SRAS is sufficiently high. However, for the purposes of the economic assessment, a value needs to be place on the costs to consumers of a failure of all procured SRAS sources so that the incremental benefits of improved SRAS aggregate reliability can be assessed. The Deloitte Access Economics report refers to this value as the "default blackout duration".

Therefore, within the economic assessment it has been assumed that when all SRAS units fail to operate then an alternative manner to restart the system will be found. Further, it has been assumed that the minimum level of generation that provides acceptable stability in each sub-region (G_{min}) is reached before T_{max} when the battery systems for operating the transmission substations may become flat.

The impact of this assumption on the economic assessment could be high when considering a single SRAS source within an electrical subnetwork because of the reliance on this single source. However, as the procurement of multiple SRAS sources is considered the probability of all SRAS sources failing to operate reduces, thus reducing the impact on the economic assessment.

5.2.3 Key parameters for the economic assessment

The key parameters for the economic assessment of SRAS are:

- the estimated probability of outage (outage frequency);
- the estimated value of unserved energy based on VCR; and

82 This assumption is based on advice from AEMO relating to the historical availability of SRAS capable generators.

- the reliability and availability of potential restart services

Table 5.1 displays the estimated black system outage frequencies which are the result of Deloitte's statistical analysis of major historical outages.

Table 5.1 Estimated Black System Event Frequency[83]

Electrical Sub-Network	Lower Bound (years)	Base Case (years)	Upper Bound (years)
North Queensland	34	30	26
South Queensland	48	43	38
New South Wales	45	38	31
Victoria	38	34	29
South Australia	20	18	17
Tasmania	25	22	19

Table 5.2 displays the regional and time specific VCR values used to value the unserved energy in the economic assessment of SRAS.

Table 5.2 Adjusted VCR Values[84]

Outage Duration	Queensland ($/kWh)	New South Wales ($/kWh)	Victoria ($/kWh)	South Australia ($/kWh)	Tasmania ($/kWh)
0-1 hours	50.53	47.76	47.57	46.56	34.18
1-3 hours	41.63	40.60	40.47	40.22	31.14
3-6 hours	28.26	27.37	25.96	27.70	21.37
6-12 hours	17.62	17.97	17.00	17.89	13.53
Average	34.51	33.42	32.75	33.09	25.05

Table 5.3 displays the average reliability and availability values for SRAS as historically offered in each of the electrical sub-networks in the NEM. These values represent the average reliability of a single SRAS source in each of the sub-networks and provide an indication of the relative reliabilities of the available restart services. When multiple SRAS sources are procured the resultant aggregate reliability will be increased. For example if two services with individual composite reliability of 80% were procured, the

83 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, p.8.

84 AEMO Value of Customer Reliability – Final Report, 28 November 2014.

resultant aggregate reliability would be 96% (1- (1-0.8) ×(1-0.8) = 0.96). Further detail on the reliability of SRAS is available in the Appendix D of the Economic Assessment of SRAS Report by Deloitte Access Economics.

Table 5.3 Average SRAS Reliability and Availability by Electric Sub-Network[85]

Sub-Network	Average Reliability	Average Availability	Average Composite Reliability[86]
North Queensland	76%	95%	72%
South Queensland	87%	95%	82%
New South Wales	81%	95%	77%
Victoria	86%	95%	81%
South Australia	84%	95%	80%
Tasmania	88%	95%	83%

5.3 Economic Assessment Results

This section provides the results from the Deloitte Access Economics economic assessment. The results have been separately presented for each of the current electrical sub-networks in the NEM.

The economic assessment used the input data and assumptions described above to estimate the impact of different levels of procured SRAS on the cost to consumers of a major supply disruption. The marginal benefits of SRAS were derived from these costs estimates and then compared to the marginal costs of SRAS to determine the economically efficient level of SRAS for each current electrical sub-network.[87] Sensitivity studies were also performed to account for the range of uncertainty associated with the key input variables of the probability of a black system condition, the regional VCR and the reliability of the SRAS sources. The results show that, for each electrical sub-network, the first SRAS source procured provides a large benefit, with the diminishing returns of procuring each additional unit of SRAS.

The Panel used these results as a guide when setting the time, level and aggregate reliability components of the Draft Standard in each electrical sub-network. The Panel recognise that variables used in this assessment are subject to change and the results in

85 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, raw data provided by AEMO.

86 Composite reliability is the combination of reliability and availability, as distinct from aggregate reliability, which is the aggregate of the composite reliabilities of the procured SRAS in an electrical sub-network.

87 The analysis by Deloitte Access Economics compared actual marginal SRAS costs with the associated marginal benefits, however the actual SRAS costs cannot be published because they are confidential. The average SRAS cost is shown as an approximate indication of the cost of SRAS which is based on AEMO's 2014 SRAS Tender Process report.

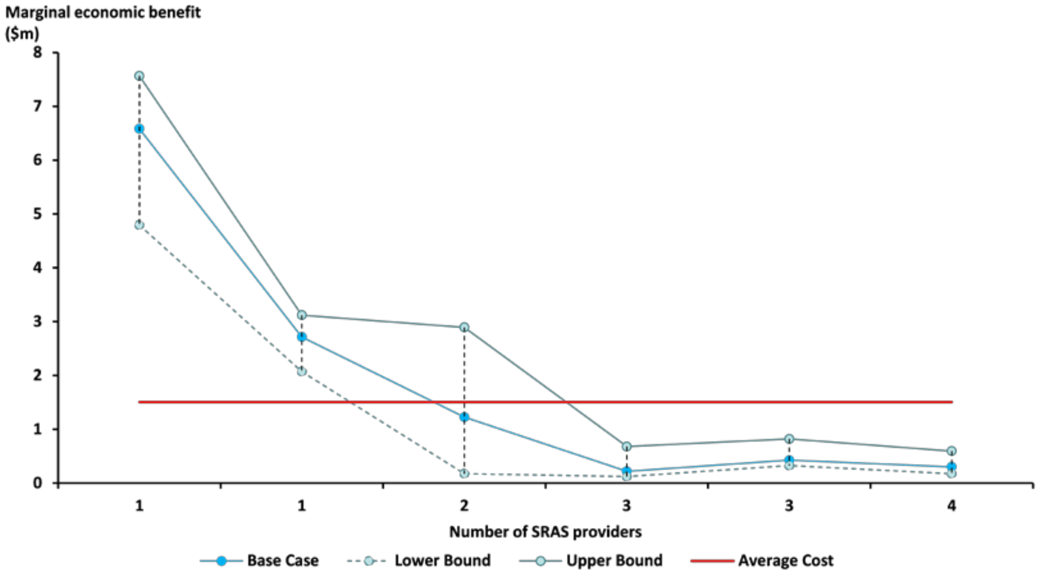
section five represent the Panels view of the appropriate level of the Draft Standard based on the currently available information in each electrical sub-network.

5.3.1 North Queensland

The results of the economic assessment performed by Deloitte Access Economics indicate that an economically efficient level of SRAS procurement for the North Queensland electrical sub-network would be two SRAS sources, with a range of between one and three SRAS sources when uncertainty is considered.

Figure 5.1, shows the estimated marginal benefit of SRAS in North Queensland, along with the average cost of SRAS based on the AEMO's 2014 SRAS procurement process.

Figure 5.1 North Queensland - Marginal Benefit of SRAS[88]



The North Queensland electrical sub-network is a long radial network, covering a length of 1500kms from north to south. This means that one SRAS source in the north of the electrical sub-network is unable to restart the whole sub-network, due to the long distance and the relatively small amount of generation in the north. However, there is a larger amount of generation in the south of this electrical sub-network so SRAS in the south can restart the whole sub-network, starting from the south.

5.3.2 South Queensland

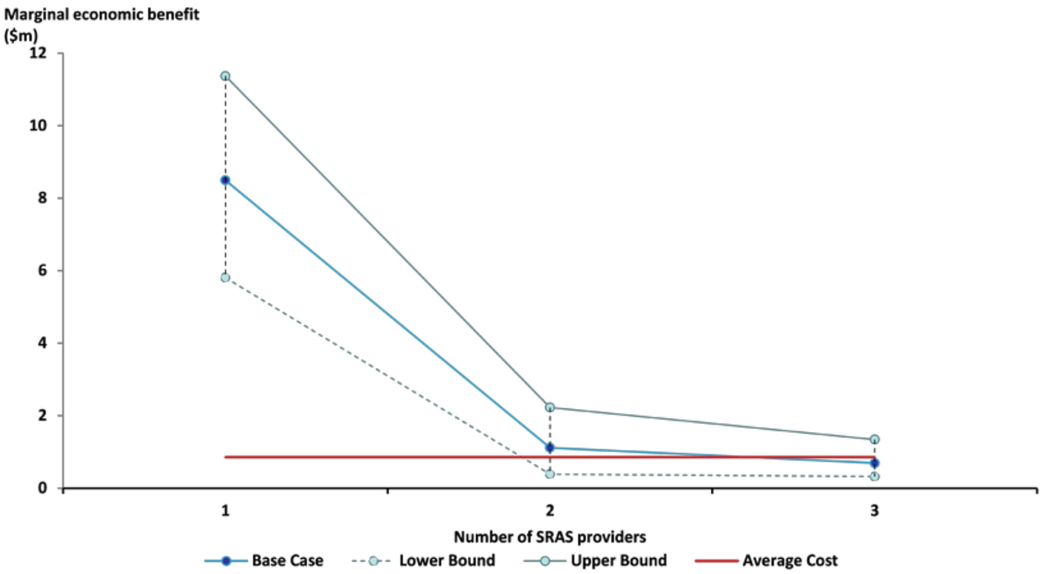
The results of the economic assessment indicate an economically efficient level of SRAS procurement for the South Queensland electrical sub-network to be one SRAS source, with a range of between one and three SRAS sources when uncertainty is considered.

Figure 5.2, shows the estimated marginal benefit of SRAS in South Queensland, along with the average cost of SRAS based on the AEMO's 2014 SRAS procurement process. One factor that increases the range of the economically efficient level of SRAS in the South Queensland sub-network is the comparatively low historical cost for SRAS in

88 Note that the two scenarios labeled “1” and “3” indicate different SRAS configurations.

South Queensland[89], with a third SRAS source delivering a net benefit at the high end of the uncertainty range.

Figure 5.2 South Queensland - Marginal Benefit of SRAS



5.3.3 New South Wales

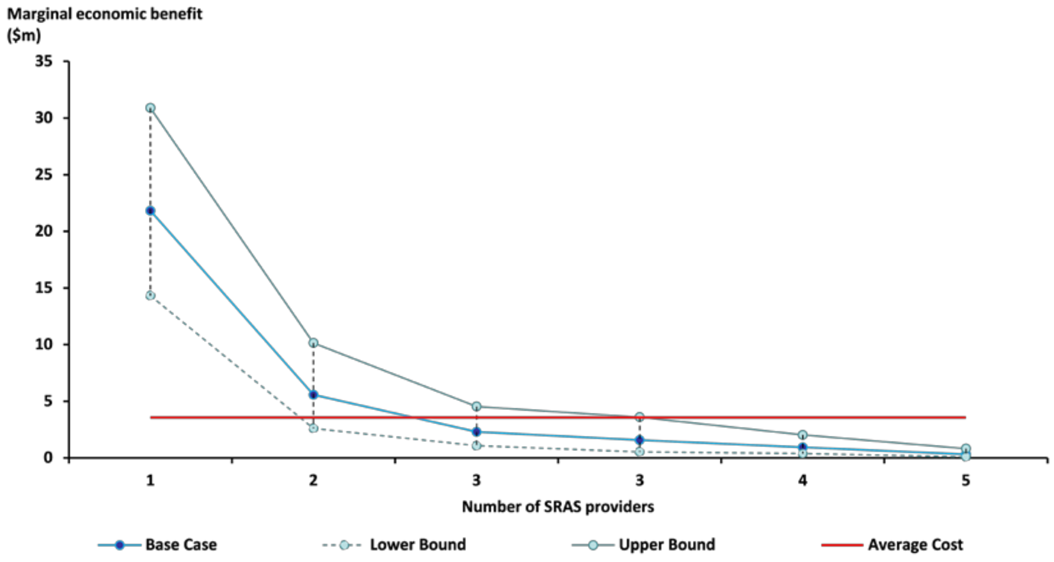
The results of the economic assessment indicate an economically efficient level of SRAS procurement for the New South Wales electrical sub-network to be two SRAS sources, with a range of between one and two SRAS sources when uncertainty is considered.

Figure 5.3, shows the estimated marginal benefit of SRAS in New South Wales, along with the average cost of SRAS based on the AEMO's 2014 SRAS procurement process. This analysis shows that the cost of a third SRAS source would be greater than expected benefit of that source, throughout the range of uncertainty considered.

The single SRAS scenario corresponds to a SRAS source in the south of the New South Wales electrical sub-network. The scenario with two SRAS providers corresponds to one SRAS source in the south of the sub-network and another in the north. A large proportion of the generation in New South Wales is north of Sydney so there is a significant benefit in a SRAS source near this generation. This is due to the delay in restoring this generation when SRAS is only available in the south of the region.

89 $853,507 in 2015, AEMO 2015 SRAS Tender Process Report

Figure 5.3 New South Wales - Marginal Benefit of SRAS[90]



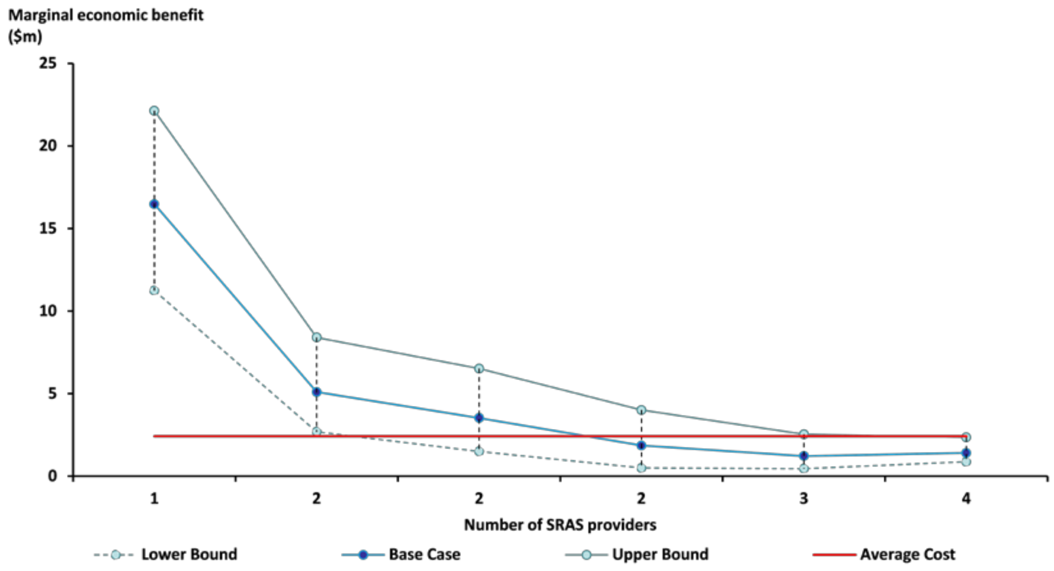
5.3.4 Victoria

The results of the economic assessment indicate an economically efficient level of SRAS procurement for the Victorian electrical sub-network to be two SRAS sources, with a range of between one and two SRAS sources when uncertainty is considered.

Figure 5.4, shows the estimated marginal benefit of SRAS in Victoria, along with the average cost of SRAS based on the AEMO's 2014 SRAS procurement process. The relatively high estimated marginal benefit for SRAS in Victoria is largely due to the relatively high expected probability of a black system condition, when compared to say New South Wales. This higher probability is the result of the relatively large number of significant security events in Victoria in recent years. When combined with a lower historical averaged cost of SRAS of $2,420,311 this leads to a larger number of SRAS sources providing a net economic benefit.

90 Note that the two scenarios labelled “3” indicate different SRAS configurations.

Figure 5.4 Victoria - Marginal Benefit of SRAS[91]

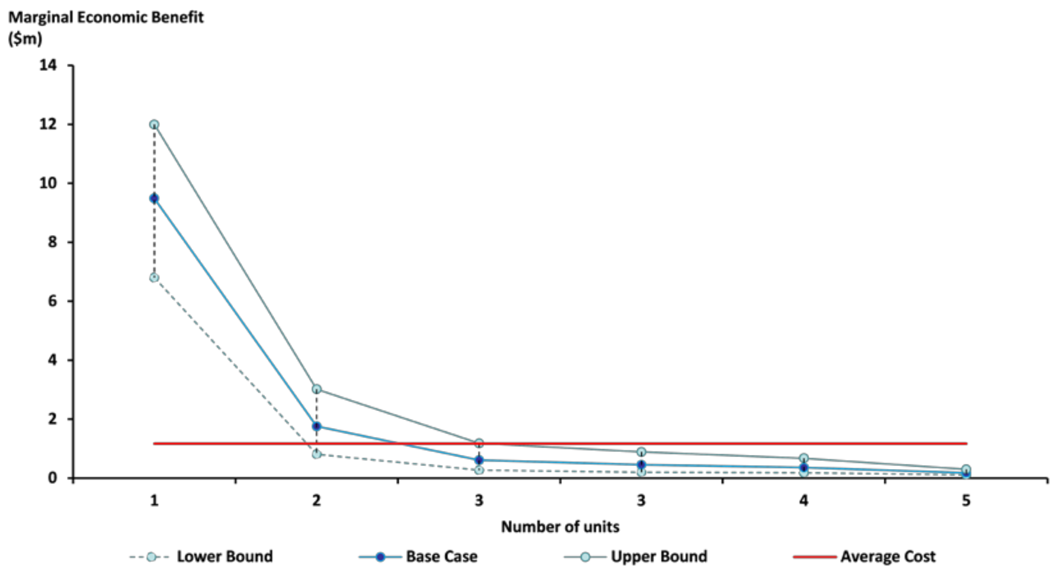


5.3.5 South Australia

The results of the economic assessment indicate an economically efficient level of SRAS procurement for the South Australian electrical sub-network to be two SRAS sources, with a range of between one and two SRAS sources when uncertainty is considered.

Figure 5.5, shows the estimated marginal benefit of SRAS in South Australia, along with the average cost of SRAS based on the AEMO's 2014 SRAS procurement process.

Figure 5.5 South Australia - Marginal Benefit of SRAS[92]



91 Note that the three scenarios labelled "2" indicate different SRAS configurations.

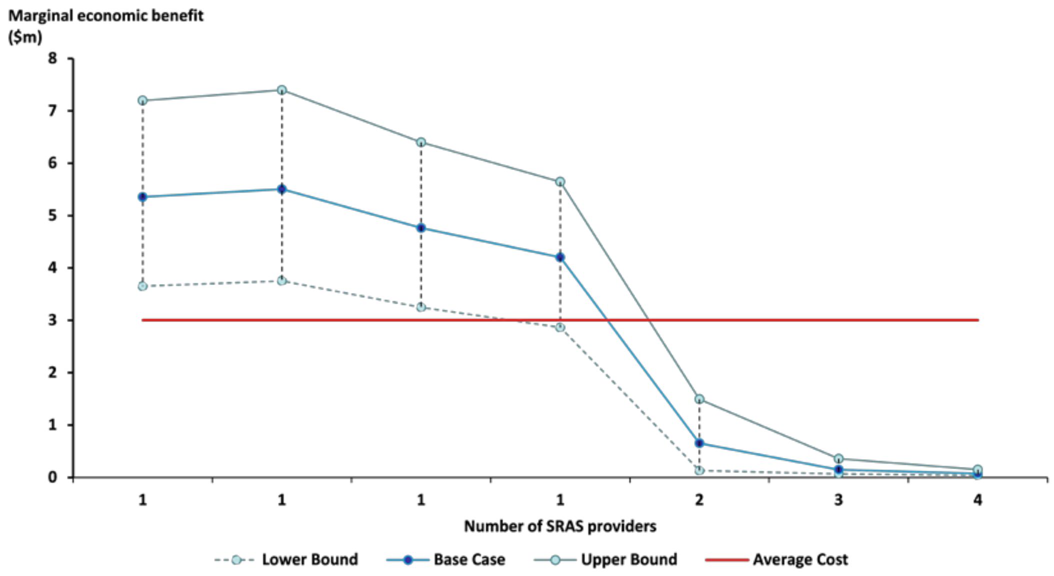
92 Note that the two scenarios labelled "3" indicate different SRAS configurations.

5.3.6 Tasmania

The results of the economic assessment indicate an economically efficient level of SRAS procurement for the Tasmanian electrical sub-network to be one SRAS source, with a range of between one and two SRAS sources when uncertainty is considered.

Figure 5.6, shows the estimated marginal benefit of SRAS in Tasmania, along with the average cost of SRAS based on the AEMO's 2014 SRAS procurement process.

Figure 5.6 Tasmania - Marginal Benefit of SRAS[93]



93 Note that the four scenarios labelled "1" indicate different SRAS options.

6 The Draft System Restart Standard

This chapter outlines the Draft Standard determined by the Panel. The chapter examines:

- the elements of the Draft Standard
- the set-points for restoration of supply under the Standard in each electrical sub-network;
- the arrangements and timing for the implementation of the Draft Standard.

The initial section displays the key elements of the Draft Standard, followed by a discussion of the Panel's considerations for each element of the Draft Standard.

6.1 Overview of the Draft System Restart Standard

Box 6.1 presents the key elements of the Draft Standard which is found in full in Appendix A:

Box 6.1 Key Elements of the Draft Standard

Time, Level and Aggregate Reliability

For each electrical sub-network, AEMO shall procure sufficient SRAS to restore generation and transmission such that supply equivalent to the prescribed level of average operational demand[94] in that sub-network, could be restored within the time defined in Table 6.1 after a major supply disruption occurring. The restoration timeframe represents the 'target time-frame' to be used by AEMO in the procurement process. It is not a specification of any operational requirement that should be achieved in the event of a major supply disruption.

In addition, for the New South Wales electrical sub-network AEMO shall procure SRAS sufficient to:

- re-supply and energise the auxiliaries of at least one major thermal coal generating unit (of at least 500 MW) north of Sydney within 1.5 hours of a major supply disruption with an aggregate reliability of at least 75%.

Aggregate reliability of SRAS

Aggregate reliability is the probability that the generation and transmission in a sub-network is expected to be restored to the specified level within the specified time. For each electrical sub-network, the required aggregate reliability shall meet

94 Operational Demand in a region is demand that is met by local scheduled generating units, semi-scheduled generating units, and non-scheduled intermittent generating units of aggregate capacity ≥ 30 MW, and by generation imports to the region. It excludes the demand met by non-scheduled non-intermittent generating units, non-scheduled intermittent generating units of aggregate capacity < 30 MW, exempt generation (e.g. rooftop solar, gas tri-generation, very small wind farms, etc), and demand of local scheduled loads.

or exceed the values shown Table 6.1.

The reliability of any individual SRAS source will incorporate the expected start-up performance and availability of that service.

The aggregate reliability of the procured SRAS in each electrical sub-network shall be determined by AEMO, considering the combination of the individual reliabilities of the SRAS procured in that electrical sub-network, together with an assessment of the impact of the points of failure set out in the guidelines for diversity in section 8 of the Standard. The concept of aggregate reliability is described further in section 6.4.

AEMO will determine the manner in which reliability will be assessed in accordance with the requirements in the Rules.

Table 6.1 Summary of the Draft Standard set-points[95]

Electrical Sub-Network	Draft Standard Level as % of Average Demand	Restoration Time-frame (hours)	Aggregate Reliability
North Queensland	45%	4.0	90%
South Queensland	25%	3.0	90%
New South Wales	20%	3.0	90%
Victoria	20%	3.0	90%
South Australia	25%	3.0	90%
Tasmania	30%	3.0	90%

Use of SRAS in neighbouring electrical sub-networks

A system restart ancillary service can only be acquired by AEMO under a system restart ancillary services agreement for one electrical sub-network at any one time.

Guidelines for the determination of electrical sub-networks

AEMO shall determine the boundaries for electrical sub-networks without limitation by taking into account the following factors:

- the number and strength of transmission corridors connecting an area to the remainder of the power system;
- the electrical distance (length of transmission lines) between generation centres; and
- an electrical sub-network should be capable of being maintained in a satisfactory operating state to the extent practicable during the restoration

95 A set-point defines a restored generation capacity, timeframe and aggregate reliability for each electrical sub-network, this id discussed further in section 6.2.1

process, and in a secure operating state from a stage in the restoration when it is practicable to do so, as determined by AEMO.

Guidelines for assessing the diversity of services

In determining the aggregate reliability of SRAS in an electrical sub-network, AEMO shall consider diversity of the services by taking into account the following guidelines:

- Electrical - diversity in the electrical characteristics shall be considered particularly with respect to whether there would be a single point of electrical or physical failure across the procured SRAS sources for each electrical sub-network;
- Geographical - diversity in geography shall be considered with respect to whether there would be any single points of failure related to the potential impact of geographical events such as natural disasters; and
- Energy Source - diversity in the energy source or fuel utilised by services shall be considered to account for any single points of failure across the procured SRAS sources for each electrical sub-network.

Guidelines for the strategic location of services

AEMO shall determine the strategic location of SRAS, based on an assessment of how the geographical and electrical location of those services best facilitates the power system restoration. The locational value of SRAS relates to its ability to energise the transmission network and assist other generating units to restart. A strategic location for an SRAS may be either within or outside the electrical sub-network for which the service is procured.[96]

6.2 Determination of the Draft Standard

6.2.1 Set-points for the Draft Standard

The Draft Standard defines a restoration set-point or set-points for each electrical sub-network in terms of:

- a level of generation and transmission capacity to be expected to be available at the end of stage 1 of the restoration process;
- a maximum time to achieve this level of generation and transmission capacity; and
- an aggregate reliability, or probability, for achieving this level within the required maximum time.

These components of the Draft Standard combine together to define the end of stage 1 of the restoration process, as described in Chapter 2. That is, through its selection of the set-points for the Draft Standard, the Panel is guiding AEMO to procure sufficient restart services from which it expects to be able to restart the power system in each

96 Clause 8.8.3(aa)(5) of the Rules.

electrical sub-network to the specified level, within the specified timeframe and with an estimated chance of success equal to or greater than the prescribed aggregate reliability.

As mentioned in section 3.2, in determining the appropriate set-points for the Draft Standard, the Panel took account of:

- the economic analysis based on the expected marginal costs and benefits of procuring different quantities of SRAS, discussed in Chapter 5; and
- the management of risk such that it is very likely that the affected transmission substations are re-energised in sufficient time to prevent a very prolonged restoration process[97].

The form of the set-points in the Draft Standard includes:

- a target level of generation and transmission restoration, equivalent to G_{min}, plus an appropriate margin;
- the allowable time to be able to achieve the level of generation and transmission capacity guided by T_{min}, plus an appropriate margin; and
- an aggregate reliability determined by the economic assessment of the marginal costs and benefits of procured SRAS.

Figure 6.1 Draft Standard set-point

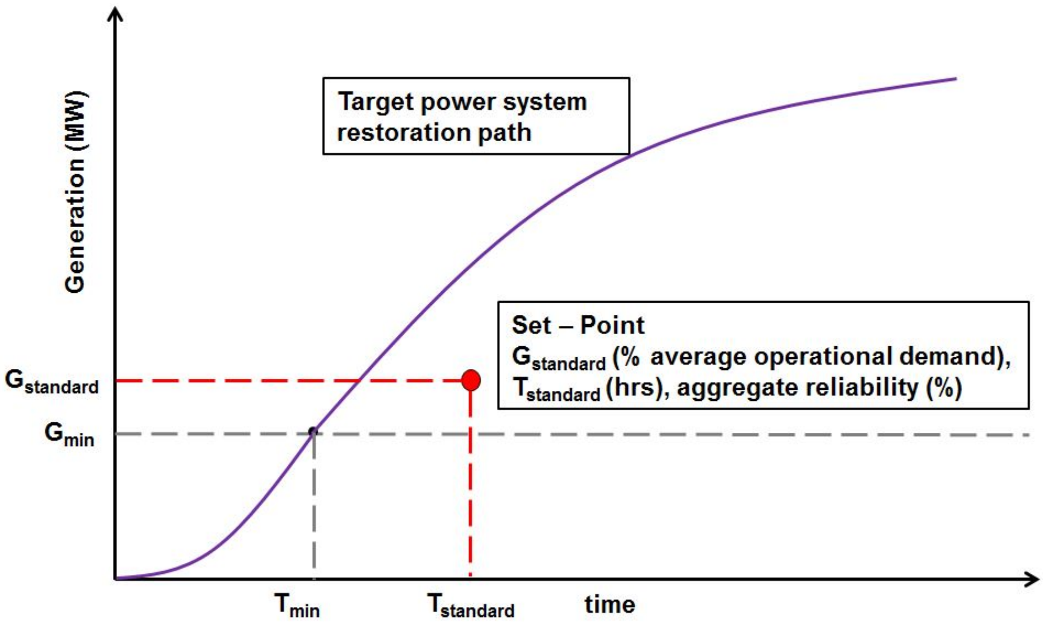


Figure 6.1 shows a generic standard set-point in relation to the target restoration path and the minimum level of generation (G_{min}). The margins above G_{min} and T_{min} provide the Standard with a level of resilience to minor changes that may occur in the power system while also providing a degree of flexibility to AEMO in applying the Standard.

97 The panel considers that a purely economic approach to defining the Standard set-points may leave consumers exposed to an unacceptable level of residual risk. The economically optimal level of SRAS is informed by balancing costs of predicted unserved energy, in the event of a major supply disruption, against the ongoing costs of SRAS. On the other hand, a risk management approach seeks to ensure that there is a high degree of certainty that the power system could be restarted in the event of a major supply disruption.

This is necessary because the values of G_{min} and T_{min} are based on the current mix of generation and transmission assets in the relevant electrical sub-network. The Panel recognises that the fundamental goal of the Standard is to provide a guide for the procurement of SRAS, such that the power system can be restored in a timely manner after a black system event, given that supply is not available from a neighbouring sub-network. Therefore, if the Standard was set too tightly, it would limit AEMO's procurement options and potentially reduce competition from potential SRAS providers. The Panel seeks to find a balance between defining a meaningful guide for the power system restoration in each sub-network and allowing a practical buffer between the set-points and the current technical capability of the power system to provide a workable flexibility for implementation of the standard[98].

6.2.2 The Panels approach to defining the set-points

As discussed in section 3.2.3, many stakeholders, including Russel Skelton and Associates, AEMO, Grid Australia and the ENA recommended that the Panel determine the level of the Draft Standard by reference to an economic assessment of the costs and benefits of SRAS. This is also required by the Terms of Reference for the Panel's review.

The Panel also considered managing the risk of a black system event when determining the Draft Standard, such that the risk of a prolonged outage is appropriately minimised. The Panel's approach to determining the appropriate level of risk took account of the perceived risk of a major supply disruption requiring SRAS[99], along with the range of restoration sources that AEMO would have at its disposal in such an event. While the Standard is defined under the assumption that supply is not available from a neighbouring sub-network, in a real situation there is likely to be power islands and neighbouring sub-networks that remain energised and can assist in the restoration. While AEMO is not able to rely on these alternative restoration sources when procuring to meet the Standard, the Panel considered the likelihood of these alternative restart supplies when it determined the aggregate required reliability component of the Draft Standard.

Therefore the Panel has used the results of the economic assessment performed by Deloitte Access Economics as a guide in setting the Draft Standard. The Panel also considered other factors such as the availability of neighbouring sub-networks with

98 The Panel recognises that the Standard should be resilient to minor changes in the characteristics of the electrical sub-networks, such as changes to the restart services that are offered to AEMO; the generation mix and the transmission network, including network augmentations and changes to the operating practices. However in the event of more significant changes the power system, or to the definition of electrical sub-networks, the Panel recognises that the Standard set-points would need to be reviewed and redefined.

99 While the economic assessment of SRAS focused on the probability and restoration of a black system covering the entirety of each individual sub network, a black system event may range in size from a part of a sub-network to a whole sub-network or even a NEM wide outage. The probability of a NEM wide outage is extremely small, although not recognised as no-zero.

inter-connectors[100]that may help in the restoration and experienced advice from the JSSCs on the perceived risk of a black system event.

The Panel's approach to defining the set-points for the Draft Standard aims to:

- guide AEMO to procure sufficient SRAS so that it is very likely that the system restart will occur within a reasonably achievable restoration time; and
- balance the aggregate reliability of this occurring with the costs of SRAS procurement.

AEMO currently procures two restart services for the majority of electrical sub-networks and many restart services consist of multiple generating units. Failure to restore generation and transmission capability to at least G_{min} within T_{max} would only occur if all individual generating units fail to operate successfully, and supply was not available from neighbouring sub-networks.

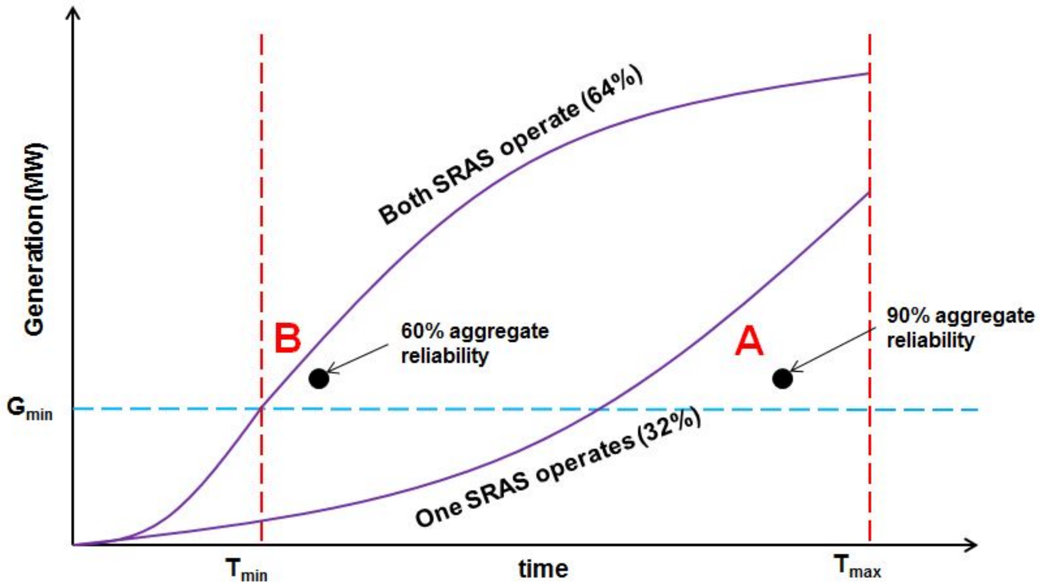
6.2.3 Interaction of the Draft Standard set-points

In practise, the individual elements of the Standard set-points interact such that time, level and aggregate reliability settings are not independent of each other and must be set as a combination for each electrical sub-network. The technical characteristics of each electrical sub-network dictate the relationship between the level of restoration and the fastest feasible time that for achieving that level, as discussed in section 4.2.1. Similarly as the aggregate reliability level for each set-point is increased the reliability of the individual SRAS sources and/or the number of sources must increase to meet the higher aggregate reliability requirement. That is, to deliver the fastest reasonably achievable restoration at a high level of reliability would require relatively large quantities of SRAS, and a correspondingly large cost of SRAS.

Figure 6.2 shows how the interaction of the time, level and aggregate reliability components of the Standard set-points lead to the possibility of equivalent procurement outcomes for different definitions of the set-point components.

100 The South Australian and Northern Queensland electrical sub-networks are only connected to the remainder of the NEM by a single interconnection so are more likely to be islanded and unable to rely on interconnection when restarting. Tasmania cannot rely on Basslink for any restarting services and must always be capable of restarting as an island.

Figure 6.2 Example of Equivalent Standard set-points



The above example is based on two SRAS sources (A&B), each with a composite reliability (availability and start up performance) of 80%.Table 6.2 shows the probabilities of the possible scenarios associated with this example.

Table 6.2 Example Probability Table

Scenario	Working	Probability
Both A & B operate	80% ×80% =	64% (80% x 80%)
A operates only	80% ×20% =	16% (80% x 20%)
B operates only	80% ×20% =	16% (80% x 20%)
Both A & B fail to operate	20% ×20% =	4% (20% x 20%)

In order to meet the requirements of set-point "A" both SRAS must be procured, giving an aggregate reliability of 96% which is greater than the requirement of 90%. This procurement outcome would be equivalent for set-point "B" where both sources combine to meet the time and level requirement with an aggregate reliability of 64% which is greater than the requirement of 60%. This example shows how the values for time, level and aggregate reliability can be varied in combination to deliver equivalent SRAS procurement outcomes. The Panel has set the standard set-points in line with point "A" in this example, where the time and level components are somewhat less stringent, while the aggregate reliability level drives the targeted SRAS procurement outcome.

6.3 Time and level aspects of the set-point

This section discusses the time and level aspects of the Draft Standard.

6.3.1 Current requirements of the Standard

The current Standard requires AEMO to procure sufficient SRAS for each electrical sub-network to:

- re-supply and energise the auxiliaries of power stations within 1.5 hours of a major supply disruption occurring to provide sufficient capacity to meet 40 per cent of peak demand in that sub-network; and
- restore generation and transmission such that 40 per cent of peak demand in that sub-network could be supplied within four hours of a major supply disruption occurring.

The current Standard applies equally in all regions. This reflected the requirements of the Rules that applied at the time the Panel last reviewed the Standard.[101] However, following the making of the SRAS rule in 2015,[102] the Standard can now vary in each electrical sub-network.[103]

6.3.2 Time requirement in the Draft Standard

The time specified in the Draft Standard for restarting a given level of generation and transmission refers to the period of time between:

- the time the associated major supply disruption event occurs; and
- the end of stage 1 of the restoration process.[104]

The Panel has considered the time requirements of the Draft Standard and is proposing different values for different regions to reflect the technical system limitations or requirements and economic circumstances of each electrical subnetwork. This is discussed in section 6.5.

6.3.3 Level requirement in the Draft Standard

Currently the level of generation and transmission specified in the Standard is set such that 40 per cent of peak demand in that sub-network could be supplied within four hours of a major supply disruption occurring. This applies equally in all regions of the NEM.

This requirement was chosen because it was considered that this marks a point in the restoration process at which most of the available network paths would need to have been restored.[105] This level was not changed when the Panel reviewed the Standard in 2012.[106]

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101 Reliability Panel AEMC, Final Determination (System Restart Standard), 12 April 2012.

102 AEMC, System Restart Ancillary Services Rule Change, Final Determination, 2015.

103 Clause 8.8.3(aa)(4) of the Rules.

104 The end of stage 1 of the restoration process is when there is sufficient generation and the transmission network operating to supply the auxiliary loads and restart all the other generating units required to ultimately meet the load when the major supply disruption ends.

105 AEMO (then NEMMCO), Interim System Restart Standard, 3 November 2006, p.7.

106 Reliability Panel AEMC, Final Determination (System Restart Standard), 12 April 2012.

Some stakeholders consider that the level (and the time) requirements of the Standard should refer to the actual restoration of consumer load, rather than just generation and transmission capability.[107] The Panel does not agree but considers that the Draft Standard should continue to be specified in terms of a level of generation and transmission network capability. This is because the Panel considers that:

- the Rules requires that the Standard is specified in terms of the maximum amount of time to restore supply,[108] which is defined in chapter 10 of the Rules as "the delivery of electricity". The Panel interprets supply to be the operation of sufficient generation and transmission network capability to be able to meet the load, rather than the actual restoration of load;
- the main purpose of SRAS is to restart the power system in the affected electricity sub-network so that further generation can be restarted and so that load can ultimately be restored; and
- the process for reconnecting load can be slow and is managed by the distribution network businesses, and so is beyond AEMO's direct control.

For these reasons the Panel considers that the Standard can not specify a requirement for the restoration of load as that would be a contrary to the requirements of the Rules and be a departure from the primary focus of the Standard which is the restoration of supply. In addition, the Panel considers specifying the Standard in terms of load restoration would also create an excessively complex compliance burden for AEMO due to the uncertainty associated with the timing of load restoration.

The Panel further considers that the specified level of supply in the Draft Standard should reflect the level of generation and transmission capability necessary to be able to supply the auxiliary loads and restart all the other generating units required to ultimately meet the load. This is referred to a G_{min} and is discussed in section 4.3.1. For generation to be regarded as contributing to achieving the Draft Standard it would need to be synchronised, or otherwise connected, to the transmission network[109].

While the value of G_{min} for a given electrical sub-network is measured in MW, the Panel has specified the Draft Standard as a percentage of average operational demand in that region[110]. This was achieved simply by dividing G_{min} by the value for the average operational demand[111]. The Panel chose this approach because it considers that:

- the average operational demand is relatively stable over time compared to the current specification of peak demand, which can vary significantly between years due to extreme weather; and
- specifying the level of minimum generation necessary in MW would be specific to the current generation and load characteristics of each electrical sub-network,

107 Russel Skelton and Associates, Submission to the Issues Paper, p.2.

108 Clause 8.8.3(aa)(2) of the Rules.

109 Planning for the restoration of load is managed through the AEMO system restart plan and the relevant TNSP black start plans which are discussed in section 2.2.1.

110 Reference to AEMO definition document ….

111 The average operational demand used here is the average of all 30 minute demands from 2005 through to May 2015.

rather as a percentage the absolute value of generation is able to reflect changes in the sub-network load over time.

The Panel has considered the generation and transmission level requirements of the Draft Standard and is proposing different values for different regions to reflect the technical system limitations or requirements and economic circumstances of each electrical subnetwork. This is discussed in section 6.5 below.

6.3.4 Removal of the intermediate requirement after 1.5 hours

In addition to the requirements to restore supply to a sufficient level after four hours, the current Standard requires AEMO to procure sufficient SRAS to re-supply and energise the auxiliaries of power stations within 1.5 hours of a major supply disruption occurring to provide sufficient capacity to meet 40 per cent of peak demand in that sub-network.

Submissions on this aspect of the Standard generally indicated that this requirement adds little value as the main object of the Standard is to ensure sufficient generation and transmission is available at the end of stage 1 to complete the restoration process. Further, AEMO stated that the inclusion of this requirement may inadvertently exclude some SRAS sources that do not meet this 1.5 hour requirement but can still contribute to the more important objective of meeting the level of generation and transmission requirements within, currently, four hours.[112]

GDF SUEZ Australian Energy (GDF SUEZ) suggested that having this intermediate step provides a degree of transparency that was useful as a guide both AEMO and potential SRAS providers.[113]

The Panel considers that the potential risk of the intermediate requirement at 1.5 hours could restrict AEMO from procuring some SRAS sources outweighs the transparency concerns raised by GDF SUEZ. The Panel is concerned that any restriction on the SRAS AEMO can procure could reduce competition for the provision of these services and hence increase the SRAS procurement costs. Therefore, the Panel has removed this intermediate requirement at 1.5 hours from the Draft Standard.

6.3.5 Consideration of sensitive loads

A number of stakeholders raised concerns relating to the restoration of supply to sensitive loads[114]in the event that such loads are impacted by a major supply disruption. Russel Skelton and Associates suggested that sensitive loads such as aluminium smelters should be given priority by setting the standard in terms of load restoration, and defining special electrical sub-networks focused on the existence of sensitive loads and their subsequent restoration.[115]Similarly, TransGrid suggested that "the Panel should give consideration to whether the Standard should outline

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112 AEMO, Submission to the Issues Paper, p.4.

113 GDF SUEZ Australian Energy, Submission to the Issues Paper, p.2.

114 The term sensitive load is defined in Chapter 10 of the Rules as "Loads defined as sensitive for each *participating jurisdiction* by the *Jurisdictional System Security Coordinator* for that *participating jurisdiction*."

115 Russel Skelton and Associates, Submission to the Issues Paper, p.27., p.36.

expectations for restoration of sensitive and critical loads within the appropriate timeframe".[116]

The Rules allows the Panel to vary the Standard to the extent necessary:

> "to reflect any specific economic circumstances in an *electrical sub-network*, including but not limited to the existence of one or more *sensitive loads*;[117] "

The set-points in the Draft Standard are tailored for each electrical sub-network based on the specific generation, network and economic characteristics of those sub-networks, supported by the economic assessment of SRAS undertaken by Deloitte Access Economics. This analysis incorporated a regionally specific value of unserved energy based on VCR that accounts for direct connect customers, which includes sensitive loads.

The Panel considers that it is not necessary for the Draft Standard to specifically provide for the existence of sensitive loads. This is because in considering the technical characteristics of each sub-network, and the economic assessment of varying levels of SRAS with each sub-network, the Panel is of the view that the Draft Standard adequately provides for the economic circumstances of sensitive loads. In the event the individual sensitive loads require an increased level of protection from major supply disruptions over and above that provided to them under the Draft Standard, then a solution is best negotiated between that load, the respective TNSP and generators, as well as potentially with the jurisdiction.

Further, as has been noted earlier in the draft determination, the Draft Standard does not address the restoration of customer load. Therefore, in response to TransGrid's concerns relating to the restoration of sensitive loads, the Panel considers that it would not be appropriate for the Draft Standard to outline expectations for restoration of sensitive and critical loads within a specified timeframe.

6.4 Electrical sub-network aggregate reliability

This section discusses the aggregate reliability component of the Draft Standard.

6.4.1 Current requirements of the Standard

The current Standard includes a reliability requirement on individual restart services. This reliability requirement has two levels:

- primary restart services with 90% reliability or more; and
- secondary restart service with 60% reliability or more.

Where this level of reliability is met AEMO can procure the SRAS to contribute to satisfying the Standard. The procurement preference is given to primary restart services, such that secondary restart services are only contracted in the event that there

116 TransGrid, Submission to the Issues Paper, p.2.

117 Clause 8.8.3(aa)(4)(B) of the Rules.

are no more primary restart services available for use in a particular electrical sub-network.[118]

Individual restart services that do not meet the required level of reliability are currently not procured by AEMO.

6.4.2 The requirement to include aggregate reliability in the Standard

In the 2015 SRAS rule change; the Commission removed the concept of "primary" and "secondary" restart services and introduced a requirement for the Standard to include an “aggregate reliability” for each electrical sub-network. [119] This change was made to allow AEMO to procure a range of different restart services with different individual levels of reliability while maintaining an appropriate level of aggregate reliability for each sub-network, potentially increasing the range of restart services that AEMO may be able to procure to meet the Standard.[120]

The Panel considered a number of possible ways of specifying the aggregate reliability of an electrical sub-network. These included specifying:

- the probability that the level of restoration required by the Standard will be delivered using the contracted SRAS;
- the minimum number of services; and
- the deterministic standard, for example "N-1 restart services are required to satisfy the Draft Standard".

A number of stakeholders opposed specifying aggregate reliability as a minimum number of restart services. The Major Energy Users (MEU) considered this was equivalent to insuring twice for the same problem[121] and AEMO considered that this would increase the cost but was unlikely to increase the speed of the restoration.[122] Grid Australia and ENA[123] consider outcomes should be based on probability analysis and Russ Skelton and Associates considered that the aggregate reliability should be determined economically.[124]

The Panel interpreted the aggregate reliability of SRAS for an electrical sub-network to be the probability that the level and time components of the Draft Standard would be satisfied, given the restart services procured and the assumptions made during the procurement process.

118 AEMO SRAS Guidelines, 2014, p.16.

119 Clause 8.8.3(aa)(3) of the Rules

120 AEMC, System Restart Ancillary Services) Rule Change, Final Determination, 2015.

121 MEU, submission to the Issues Paper, p.3-4.

122 AEMO, submission to the Issues Paper, p.5.

123 Grid Australia and ENA, submission to the Issues Paper, p.5.

124 Russ Skelton and Associates, submission to the Issues Paper, p.37-38.

6.4.3 Application of the aggregate reliability by AEMO

When AEMO procures SRAS it will be required to satisfy the required level of aggregate reliability in meeting the time and level requirements of the Standard in each electrical sub-network.

This will require AEMO to consider the reliability values of the individual restart services that it procures. The Panel considers that AEMO will need to take into account a range of factors including:

- the availability of the generating units and network elements that make up the SRAS contracts;
- an estimate of the probability that a restart service would operate correctly when it is available and activated; and
- the level of redundancy available within a SRAS contract, that is whether the restart service is provided by a number of individual generating units.

The Draft Standard also includes a linkage between the determination of aggregate reliability for each electrical sub-network and the diversity guidelines. In fulfilling this element of the Draft Standard, AEMO will need to identify potential single points of failure across the SRAS portfolio for each sub-network and incorporate an estimate of the probability of these single point failures into its calculation of the aggregate reliability for the electrical sub-network. The linkage between the aggregate reliability for the electrical sub-network and the diversity guidelines is discussed further in section 6.8 below.

AEMO is responsible for determining the detailed process for how aggregate reliability will be assessed in the SRAS Guideline.[125] Amending the guideline will require consultation with relevant stakeholders.[126]

6.5 Set-points for the Draft Standard in each electrical sub-network

The Draft Standard defines a restoration set-point or set-points for each electrical sub-network in terms of:

- a level of generation and transmission capacity to be expected to be available at the end of stage 1 of the restoration process;
- a maximum time to achieve this level of generation and transmission capacity; and
- an aggregate reliability, or probability, for achieving this level within the required maximum time.

The context for the definition of these set-points is discussed further in section 6.2.1

The sub-network specific levels in the Draft Standard are based on the values of G_{min},[127] rounded up to the nearest 5% and expressed as a percentage of averaged operational demand. The level set-points for the Draft Standard are presented in Table 6.1.

125 Clause 3.11.7(d)(2) of the Rules.

126 Clause 3.11.7(e) of the Rules.

The restoration time for each electrical sub-network was taken by finding the time intersection for the restoration curves and the level of G_{min} above which includes a buffer to provide a level of flexibility in the Draft Standard.

The Panel selected the aggregate reliability for each electrical sub-network with consideration for the economically optimal level of SRAS, estimated in the Deloitte Access Economics report. The aggregate reliability is an important driver for the number of SRAS sources, as a higher level of aggregate reliability requires AEMO to either procure more reliable SRAS or additional SRAS to meet the aggregate reliability requirement. The Panel determined the aggregate reliability for the SRAS in each electrical sub-network from the theoretically optimal number of SRAS sources, as estimated by Deloitte Access Economics. Table 6.3 provides a summary for each electrical sub-network of the theoretical optimal number of SRAS sources and the aggregate reliabilities these SRAS sources would be expected to provide.

Table 6.3 Range of Aggregate Reliabilities

Electrical Sub-Network	Theoretically optimal number of SRAS sources	Corresponding range of aggregate reliabilities
North Queensland	1-2	85.5% - 98.6%
South Queensland	1-2	90.3% - 97.2%
New South Wales	1-2	85.5% - 97.8%
Victoria	1-2	87.9% - 98.2%
South Australia	1-2	85.5% - 97.0%
Tasmania	1	71.25% - 90.25%

The Panel considered the range of aggregate reliability values from the economic assessment of SRAS and determined that the aggregate reliability for each of the electrical sub-networks should be 90%. The Panel considers that this level:

- Is not so high as be likely to unduly restrict the potential SRAS sources that AEMO could procure; and
- meets stakeholders' expectations for SRAS reliability, while being consistent with the economic assessment by Deloitte Access Economics.

The set-points in the Draft Standard are specific to the existing sub-network boundaries, as defined by AEMO in the SRAS Guidelines. The consequences of AEMO changing the sub-network boundaries are discussed in section 7.6.

6.5.1 North Queensland

The set-point for the North Queensland electrical sub-network in the Draft Standard is that SRAS shall be procured with the target of restoring generation and transmission capacity to a level equal to 45% of historical average operational demand within four

127 The definition of G_{min} is discussed in section 4.3.1.

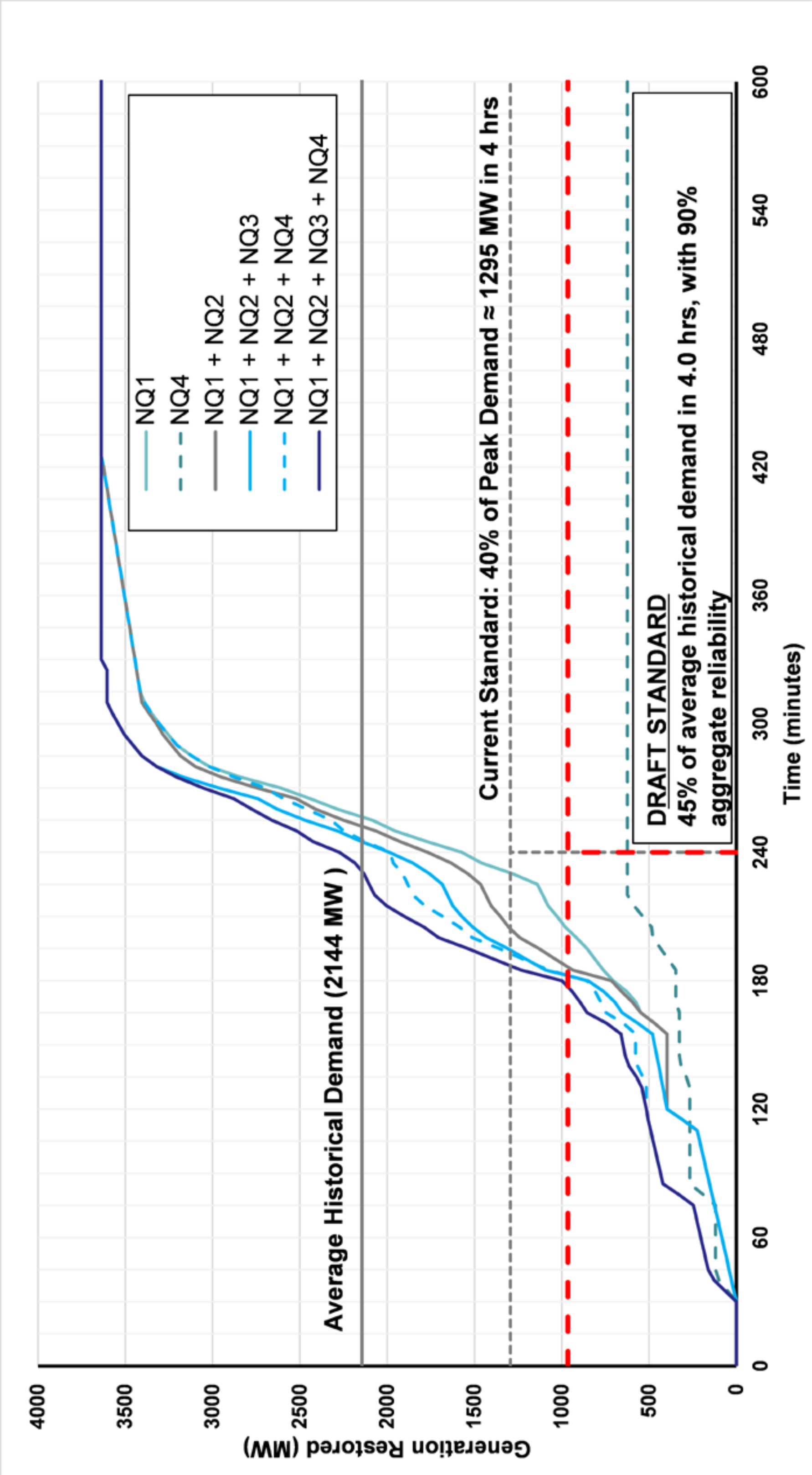
hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90%, as discussed in section 6.5 above.

In defining this set-point, the Panel has considered the results of the economic assessment outlined in Chapter 5 and the specific regional characteristics of the North Queensland electrical sub-network. The North Queensland sub-network is a long radial network that lies at the northern extremity of the NEM, and can be exposed to tropical storms. The time and level requirements of the set-point reflect the technical capability and limitations of the available SRAS sources and power system, including a small buffer to account for possible changes in the future. The long distances between the generation centres and relatively low load density in North Queensland, contribute to the longer restoration time of 4 hours.[128]

Figure 6.3 shows the restoration curves for the North Queensland electrical sub-network, along with the set-points from the current and Draft Standard the system restart standard.

128 The long distances between generation centres and lower load density contribute to the initial transmission restoration process being slower than other electrical sub-networks, as generation and load must be progressively balanced during the restoration process.

Figure 6.3 North Queensland Draft Standard set-point



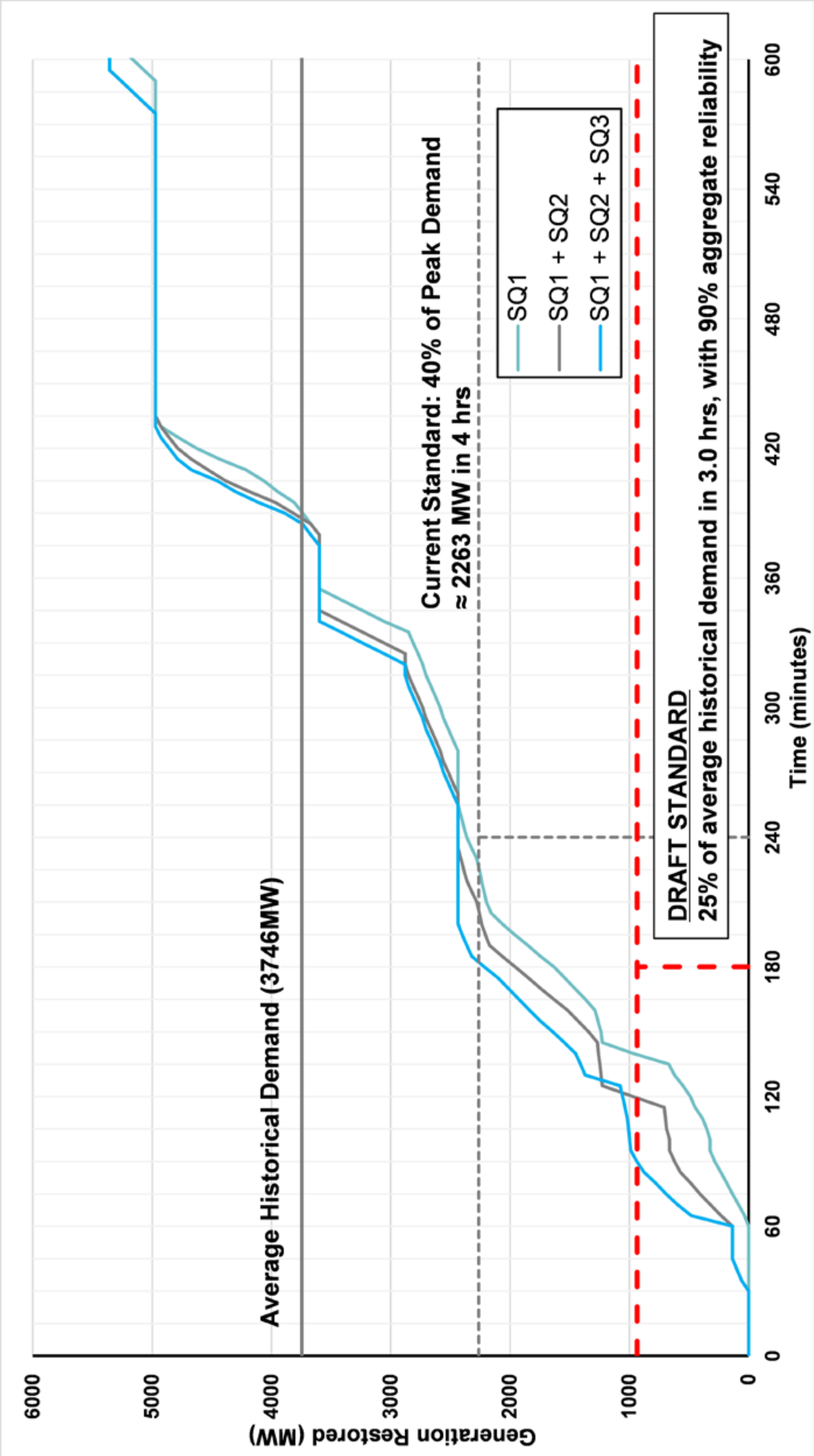
6.5.2 South Queensland

The set-point for the South Queensland electrical sub-network in the Draft Standard is that SRAS shall be procured with the target of restoring generation and transmission capacity to a level equal to 25% of historical average operational demand within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90%, as discussed in section 6.5 above.

Figure 6.4 shows the restoration curves for the South Queensland electrical sub-network, along with the set-points from the current and Draft Standard.

In defining this set-point, the Panel considered the results of the economic assessment outlined in Chapter 5 and the specific regional characteristics of the South Queensland electrical sub-network. The South Queensland sub-network is a strongly interconnected transmission system with a relatively short electrical distance between the major generation and load centres. The time and level requirements of the set-point reflect this and include a small buffer to account for possible changes in the future.

Figure 6.4 South Queensland - Draft Standard set-point



6.5.3 New South Wales

The set-point for the New South Wales electrical sub-network in the Draft Standard is that SRAS shall be procured with the target of restoring generation and transmission capacity to a level equal to 20% of historical average operational demand within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90%, as discussed in section 6.5 above.

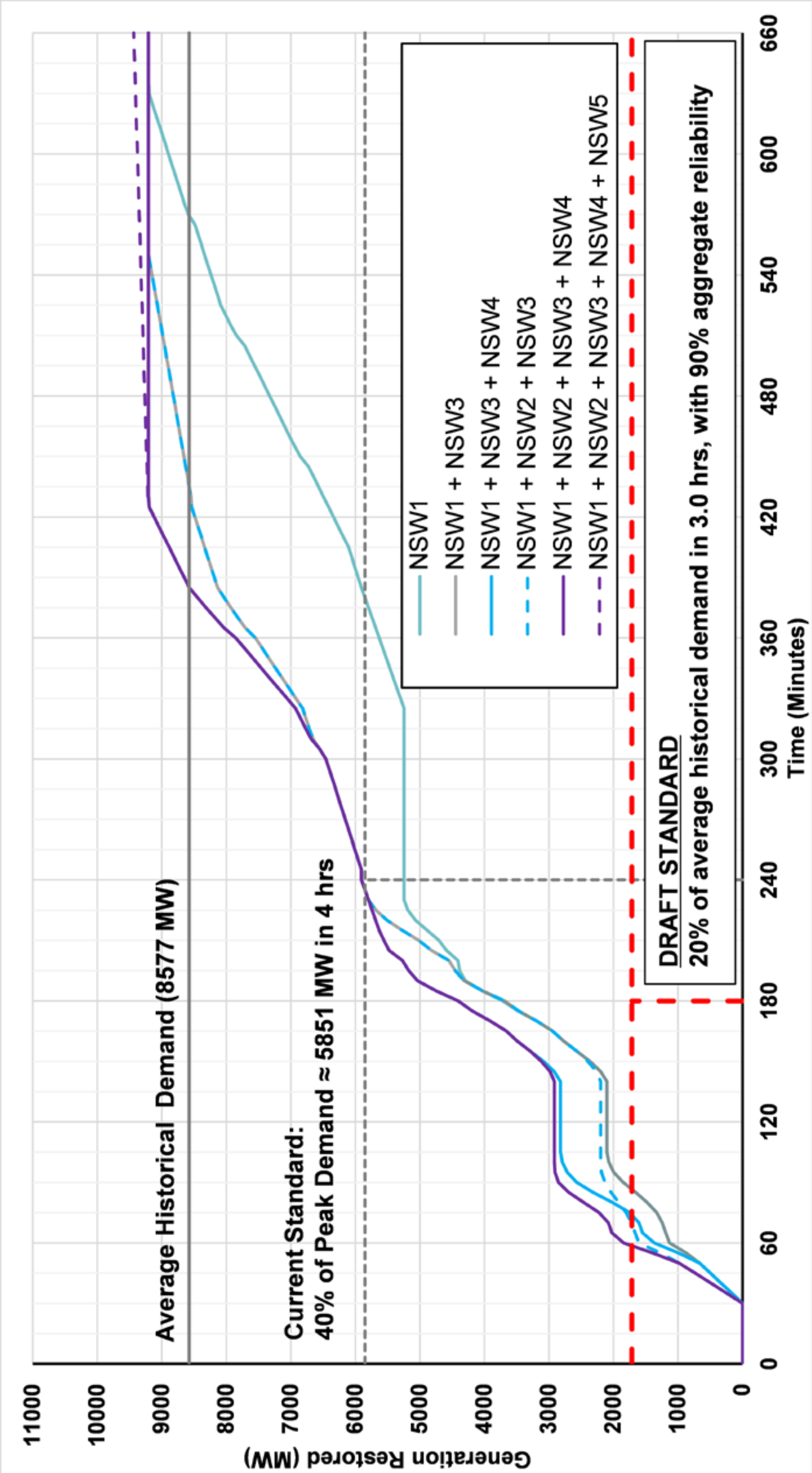
Figure 6.5 shows the restoration curves for the New South Wales electrical sub-network, along with the set-points from the current and Draft Standard. The restoration curve marked "NSW1" corresponds to a single SRAS source in the south of the electrical sub-network while the curve marker "NSW1 + NSW3" corresponds to one SRAS source in the south and one north of Sydney.[129] The area between these two curves from about 240 minutes to about 600 minutes is due to the absence of a SRAS source north of Sydney and would be expected to result in a large quantity of additional unserved energy.

In defining this set-point, the Panel has considered the results of the economic assessment outlined in Chapter 5 and the specific regional characteristics of the New South Wales electrical sub-network. The time and level requirements of the set-point reflect the technical capability and limitations of the available SRAS sources and power system, including a small buffer to account for possible changes in the future.

The New South Wales sub-network contains two major generation centres that are electrically separate. This means that an ideal restoration process would include SRAS in both of these generation centres. Therefore, the Panel has decided to include an additional requirement in the Draft Standard for the New South Wales electrical sub-network. AEMO must procure SRAS in New South Wales sufficient to resupply and re-energise the auxiliary power to at least 500MW of generation capacity north of Sydney within 1.5 hours of a major supply disruption with an aggregate reliability of at least 75%. The rationale for this additional requirement is discussed further in section 6.5.7

129 The actual contracted SRAS sources form part of the system restart plan, which is confidential information in accordance with clause 4.8.12 (b) of the Rules.

Figure 6.5 New South Wales - Draft Standard set-point



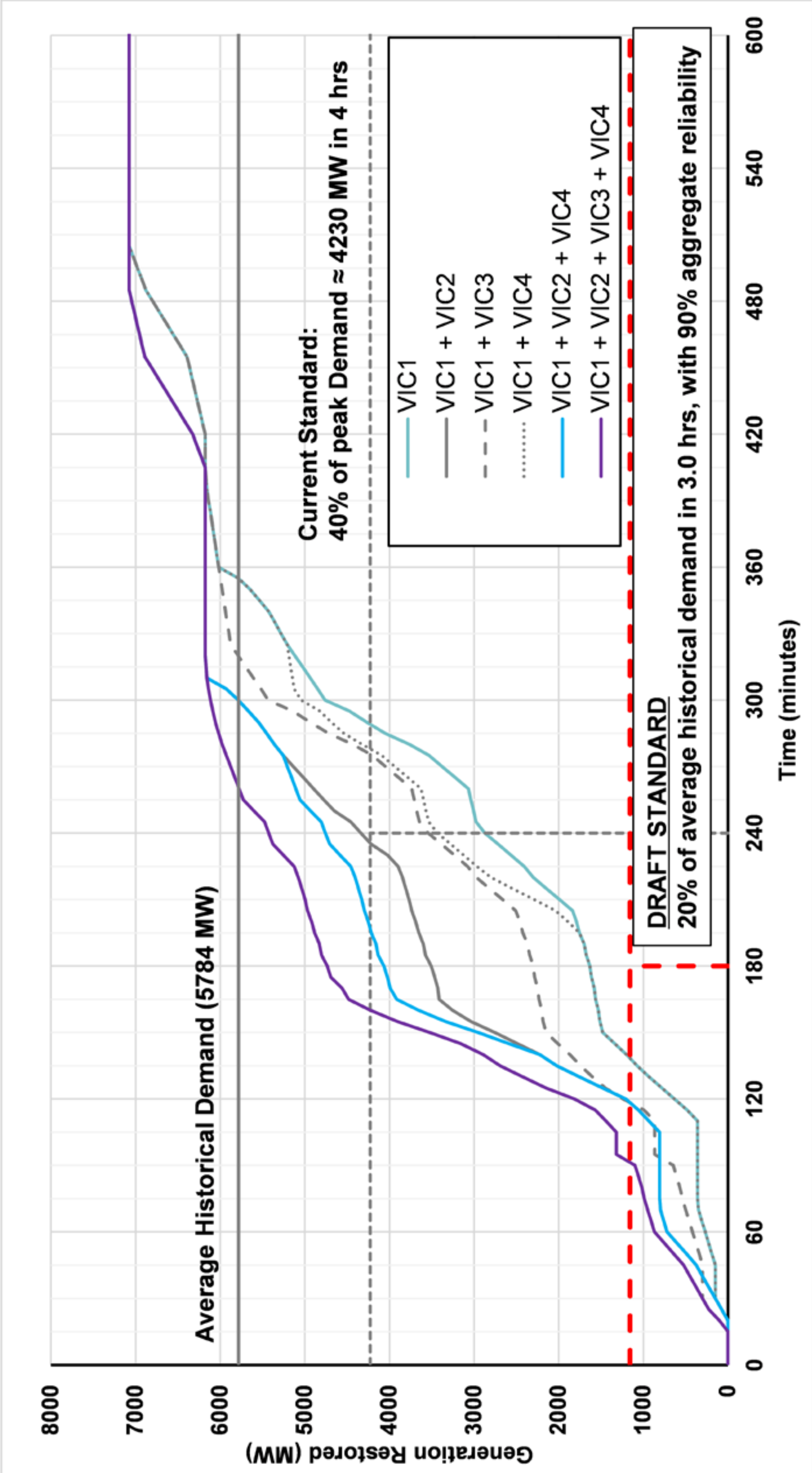
6.5.4 Victoria

The set-point for the Victorian electrical sub-network in the Draft Standard is that SRAS shall be procured with the target of restoring generation and transmission capacity to a level equal to 20% of historical average operational demand within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90% as discussed in section 6.5 above

In defining this set-point, the Panel has considered the results of the economic assessment outlined in Chapter 5 and the specific regional characteristics of the Victorian electrical sub-network. The Victorian sub-network is a strongly interconnected transmission system with a relatively short electrical distance between the major generation and load centres. The time and level requirements of the set-point reflect this and include a small buffer to account for possible changes in the future.

Figure 6.6 shows the restoration curves for the Victorian electrical sub-network, along with the set-points from the current and Draft Standard.

Figure 6.6 **Victoria - Draft Standard set-point**



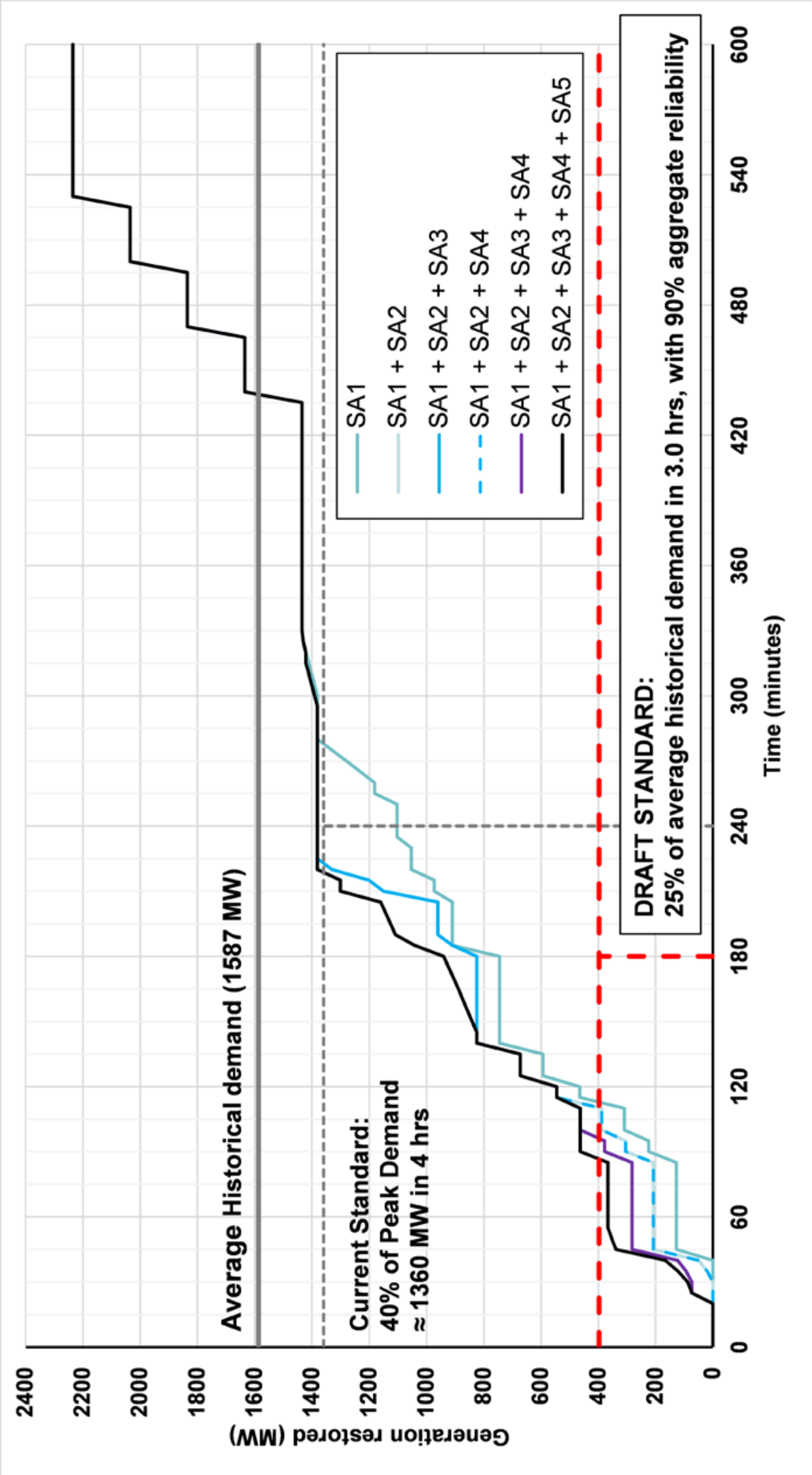
6.5.5 South Australia

The set-point for the South Australian electrical sub-network in the Draft Standard is that SRAS shall be procured with the target of restoring generation and transmission capacity to a level equal to 20% of historical average operational demand within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90%, as discussed in section 6.5 above.

In defining this set-point, the Panel has considered the results of the economic assessment outlined in Chapter 5 and the specific regional characteristics of the South Australian electrical sub-network. The South Australian sub-network is a strongly interconnected transmission system with a relatively short electrical distance between the major generation and load centres. The time and level requirements of the set-point reflect this.

Figure 6.7 shows the restoration curves for the South Australian electrical sub-network, along with the set-points from the current and Draft Standard.

Figure 6.7 South Australia - Draft Standard set-point



6.5.6 Tasmania

The set-point for the Tasmanian electrical sub-network in the Draft Standard is that SRAS shall be procured with the target of restoring generation and transmission capacity to a level equal to 30% of historical average operational demand within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90%, as discussed in section 6.5 above.

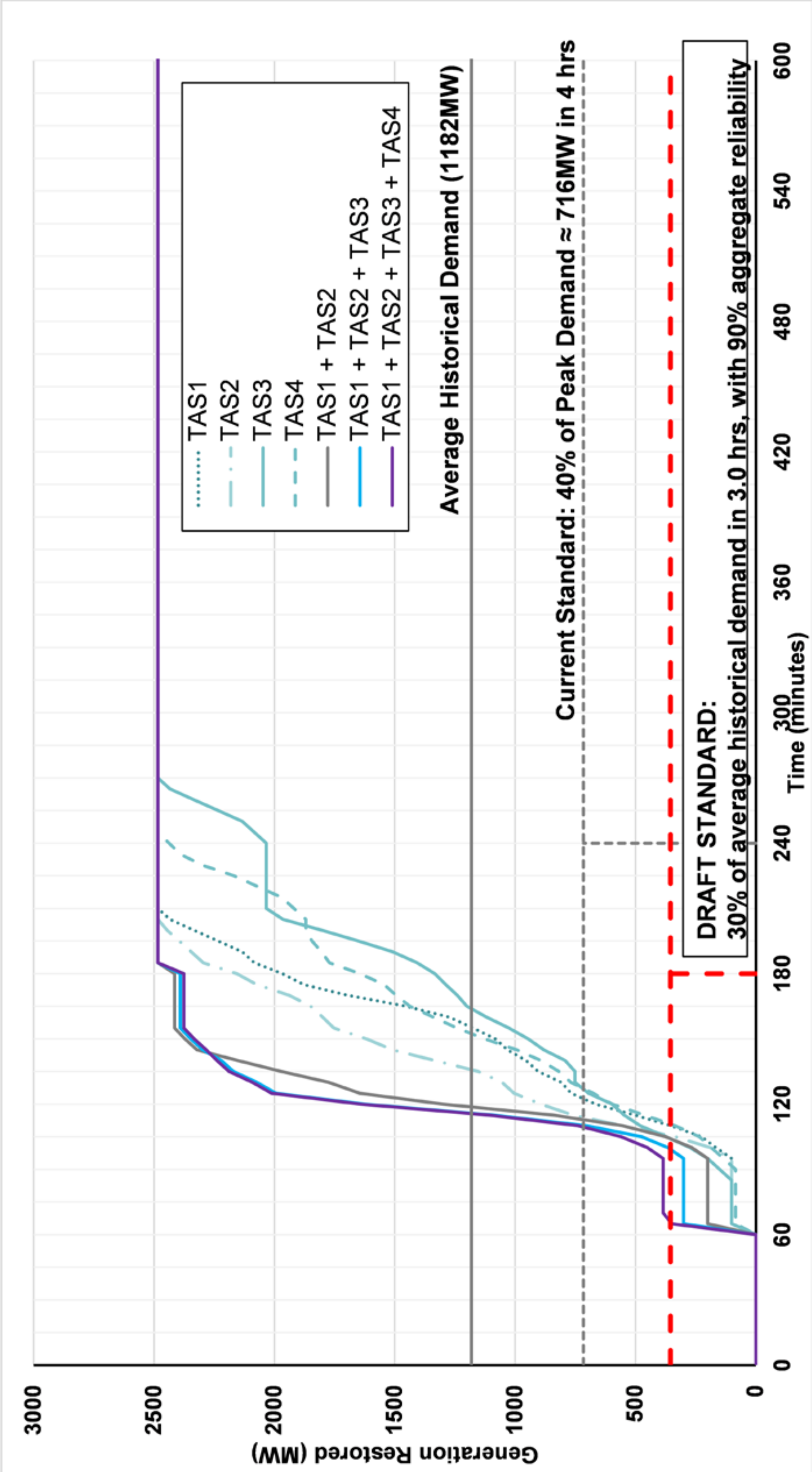
In defining this set-point, the Panel has considered the results of the economic assessment outlined in Chapter 5 and the specific regional characteristics of the Tasmanian electrical sub-network. The Tasmanian sub-network is a relatively small power system with predominantly hydro generation[130] that can start relatively quickly.[131] The time and level requirements of the set-point reflect this and include a small buffer to account for possible changes in the future.

Figure 6.8 shows the restoration curves for the Tasmanian electrical sub-network, along with the set-points from the current and Draft Standard.

130 77% of installed generation capacity in Tasmania is hydro power, as of April 2016, AEMO Generation information, http://www.aemo.com.au/Electricity/Planning/Related-Information/Generation-Information.

131 Basslink is not able to be utilised as a restart service in the event of a black system affecting either the Tasmanian of Victorian electrical sub-networks, as the power systems on either end of the cable must be energised to enable operation of the DC link.

Figure 6.8 Tasmania - Draft Standard set-point



6.5.7 Varying the Standard

The Rules gives the Panel the power to vary the Standard between regions to reflect specific technical limitations or economic circumstances[132]. The Panel chose to include an additional requirement in the Draft Standard for the New South Wales electrical sub-network, to require AEMO to procure SRAS that is sufficient to

> "Re-supply and energise the auxiliaries of at least 500 MW of generation capacity north of Sydney within 1.5 hours of a major supply disruption with an aggregate reliability of at least 75%."

This additional requirement is included on the basis of the special nature of the New South Wales generation and transmission system, which is typified by a large quantity of generation located in and around the Hunter Valley and a number of fast response hydro-power resources in the south of the state.

The long distance between the large generators in the Hunter Valley and hydro-generation in the south can lead to a delayed black system restoration if auxiliary power is not returned these large generators within a relatively short time as these generators have slower ramp rates than other scheduled generating technologies such as gas turbines or hydro-electric generation. The goal of a restart in this case becomes providing auxiliary power to these large generators to enable their warm-up process to commence, such that they can be ready to supply electricity. This process may take between 2 and 12 hours depending when auxiliary power is restored.[133]

As discussed in section 5.3.3, the results of the economic assessment suggest that the economically efficient level of SRAS for New South Wales is between one and two SRAS sources, with a greater economic benefit of a second unit being realised if that unit is available to the north of Sydney. The Panel considers that adding this additional requirement for New South Wales will clarify the requirement for an economically efficient level of SRAS to be procured in New South Wales, such that the major generators will have auxiliary power restored early on in the restoration allowing for a significantly faster restoration of the power system than may occur otherwise.

The Panel does not consider that a similar additional requirement would be appropriate for the other electrical sub-networks in the NEM. While there are large concentrations of generation in other electrical sub-networks, such as the Latrobe Valley, the Panel considers that the electrical distances are not as long as those in the New South Wales electrical sub-network and the delay to the restoration of supply from not having a SRAS source in the Latrobe Valley is relatively small, compared to the delays in New South Wales from not having a SRAS source near the Hunter Valley.

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132 NER cl 8.8.3(aa)(4)(B) " The system restart standard must:...apply equally across all regions, unless the Reliability Panel varies the system restart standard between electrical sub-networks to the extent necessary:...to reflect any specific economic circumstances in an electrical sub-network, including but not limited to the existence of one or more sensitive loads"

133 Russel Skelton and Associates, Submission to the Issues Paper, pp 26, 28

6.6 Each SRAS may only be acquired for one electrical sub-network

The 2015 SRAS rule change introduced an ability for AEMO to meet the Standard in one electrical sub-network by contracting a SRAS source from a neighbouring electrical sub-network provided that a SRAS source was only contracted to one electrical sub-network at any one time.[134] This change was implemented through a requirement that the Standard must:

> "specify that a *system restart ancillary service* can only be acquired by *AEMO* under a *system restart ancillary services* agreement for one *electrical sub-network* at any one time.[135]"

The Panel has included this requirement in the Draft Standard.

6.7 Guidance for the determination of electrical sub-networks

6.7.1 Current requirements in the Standard

The Standard must provide guidance to AEMO in its determination of electrical sub-network boundaries.[136] This includes guidance to AEMO on how to determine the appropriate number of electrical sub-networks and the characteristics required within a sub-network. AEMO is responsible for determining the boundaries between the electrical sub-networks and reporting on how it has complied with the guidelines provided in the Standard.[137]

The current guidance in the Standard is that AEMO is to take into account the following factors:

- the number and strength of transmission corridors connecting an area to the remainder of the power system;
- the electrical distance (length of transmission lines) between generation centres;
- the quantity of generation in an area, which should be in the order of 1000 MW or more; and
- the quantity of load in an area, which should be in the order of 1000 MW or more.

As mentioned in section 2.1.7, currently AEMO has determined that there are six electrical sub-networks.[138] These are Queensland North, Queensland South, New South Wales, Victoria, South Australia and Tasmania. With the exception of Queensland, the sub-networks follow the NEM region boundaries. The Queensland region is divided into two sub-networks with the boundary being on the South Pine - Palmwoods and Halys - Calvale transmission lines. AEMO considers that the borders

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134 AEMC, System Restart Ancillary Services Rule Change, Final determination, 2015, p.68.

135 Clause 8.8.3(aa)(5) of the Rules.

136 Clause 8.8.3(aa)(6) of the Rules.

137 Clause 3.11.8(aa)(6) of the Rules.

138 AEMO, Boundaries of electrical sub-networks, 27 June 2014.

between each of these sub-networks represent a transmission breakpoint,[139] where the system would be likely to separate during a large scale event.

6.7.2 Stakeholder views

A number of stakeholders raised concerns with the process and current determination of electrical sub-networks in the NEM. TransGrid suggested that AEMO should consider "significantly weaker cut-sets" than currently considered within the criteria for "number and strength of transmission corridors", along with how the definition of electrical sub-network boundaries impacted the restoration prognosis for sensitive loads following a wide-scale black system event.[140] Russ Skelton and Associates argued that the approach to setting electrical sub-network boundaries should be informed by "the economic characteristics of load in a particular region".[141]

Hydro Tasmania expressed concern relating to the current single sub-network in Tasmania and considered this represented a risk of a possible separation of the transmission system between northern and southern Tasmania during a restart event which will expose the southern sub-region to an extended black-out.[142] These concerns were reiterated when TasNetworks was consulted.

The Queensland JSSC considered that the greatest vulnerability within the Queensland transmission network was between the centre and north of Queensland. This vulnerability is due to potential exposure to cyclones and the limited number of transmission corridors, as compared to the remainder of the Queensland transmission network.

In considering the views of Hydro Tasmania, TasNetworks and the Queensland JSSC, the Panel notes that AEMO is responsible for the determination of the electrical sub-networks boundaries in accordance with the guidelines in the Standard. The Panel is responsible for determining these guidelines as a component of the Standard, but AEMO is responsible for the determination of the electrical sub-networks[143]. The Panel also understands that AEMO chose the current electrical sub-networks for Tasmania and Queensland, at least in part, because of the current requirement to include at least 1000 MW of generation and load within any electrical sub-networks.

6.7.3 Panel's considerations for the Draft Standard

The purpose of the guidelines for the determination of electrical sub-networks is to provide clear guidance to AEMO so that the restoration process is sufficiently fast and reliable following a major supply disruption. Therefore, the electrical sub-networks should reflect the characteristics of the power system with the key attributes being:

- the viability of the resultant power island from the perspective of power system operation and stability/security; and

139 Ibid, p.5.

140 TransGrid, submission to the issues paper, p.5.

141 Russ Skelton and Associates, submission to the Issues Paper, p.41.

142 Hydro Tasmania, submission to the Issues Paper

143 Clause 3.11.8 of the Rules.

- the existence of natural “break points” in the power system, being locations where network inter-connectivity is inherently weaker or more exposed to a separation style event.

The Panel has retained the first two existing factors of the current guideline in relation to transmission corridors and electrical distance as these are consistent with aligning the electrical sub-network boundaries with the natural break-points in the network.

The Panel considers that the requirement that AEMO should seek to have in the order of 1000 MW or more of load and generation in a sub-network may potentially lead to barriers in the creation of multiple sub-networks in smaller NEM regions, such as Tasmania. Therefore the Panel removed the load and generation thresholds from the electrical sub-network guidelines in the Draft Standard to reduce the potential barriers to the creation of smaller electrical sub-networks.

In place of the minimum generation and load thresholds the Panel has included an additional requirement that:

- the ability for the resultant electrical sub-network to operate as a viable island within its technical limits during normal conditions or following the contingencies.

This requirement allows AEMO to determine the lower limit for the size of an electrical sub-network, based on the characteristics of the power system, such that it is practical to restart the resultant electrical sub-network as an isolated system.

6.8 Diversity and strategic locations

6.8.1 Current requirements of the Standard

The Standard is required to include guidelines for considering diversity and the strategic locations of SRAS sources.[144] The existing Standard specifies that AEMO must consider four diversity requirements during the procurement of SRAS:

- Electrical - diversity in the electrical characteristics shall be considered particularly with respect to whether there would be a single point of electrical or physical failure;
- Technological - diversity in technologies shall be considered to minimise the reliance of services on a common technological attribute;
- Geographical - diversity in geography shall be considered to minimise the potential impact of geographical events such as natural disasters; and
- Fuel - diversity in the type of fuel utilised by services shall be considered to minimise the reliance on one particular fuel source.

6.8.2 Panel's consideration of the diversity requirements

Electrical diversity

The current Standard for electrical diversity requires consideration of whether there would be a single point of electrical or physical failure. AEMO considers that there are

144 Clause 3.11.8(aa)(7) of the Rules.

always going to be single points of failure during a restart process[145]. That is, early in the restoration process a fault may potentially return the affected system to a black system condition. This risk is managed by AEMO, TNSP and DNSP restart plans.

The Panel considers that the electrical diversity requirement should be in relation to a single point of failure for procured SRAS sources for a sub-network, and not for the network that is being restored. An example would be if there was a single electrical transmission corridor that connected all the procured SRAS with the remainder of the electrical sub-network. That corridor would represent a single point of failure, which should be considered by AEMO during its procurement of SRAS. Therefore, the Panel has clarified the requirement in the Draft Standard for electrical diversity as follows:

> "Electrical - diversity in the electrical characteristics shall be considered particularly with respect to whether there would be a single point of electrical or physical failure across the procured SRAS sources for each electrical sub-network."

Technological diversity

The factor in the guideline relating to technological diversity is intended to mitigate the potential risk that all the SRAS sources within an electrical sub-network rely on a single technology and that there is a common failure mode for this technology. As noted in the current Standard, "a restoration strategy may be less robust if the services all relied on gas supplies or all services were trip-to-house-load".

AEMO considers that while technological diversity makes sense in principle, practically it is difficult to implement as electrical sub-networks may be dominated by one or two technologies, while in Tasmania they are all hydroelectric.[146] Hydro Tasmania also thinks that the current requirement to consider technological diversity is so broad as to offer little guidance.[147]

The Panel agrees with stakeholders and considers that technological diversity should only be considered to the extent that it affects the aggregate reliability of the SRAS sources procured for a given electrical sub-network. This is discussed further above in section 6.4.

Therefore, the Panel has removed technological diversity from the guideline in the Draft Standard.

Geographical diversity

The guideline for geographic diversity is intended to guide AEMO to consider the resilience of the procured SRAS sources to events that impact an electrical sub-network region, such as earthquakes, severe storms and bushfires.

The Panel has retained geographical diversity in the guidelines of the Draft Standard, with the inclusion of a reference to any single points of failure related events that impact a particular geographical area.

Energy Source diversity

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145 AEMO, submission to the Issues Paper, p.3.

146 AEMO, submission to the Issue Paper, p.3.

147 Hydro Tasmania, submission to Issues Paper, p.10.

The current Standard includes a factor for fuel diversity in the guideline for diversity. The factor was added to the Standard by the Panel in 2012 in response to the potential exposure of South Australian SRAS to a gas supply failure.[148]

AEMO indicated that fuel diversity may be difficult to include in an assessment of SRAS diversity in some electrical sub-networks that are dominated by a single fuel source. AEMO suggests that where SRAS sources can demonstrate 12-hour local fuel storage would then this would remove the concern of relying on a fuel supply.[149]

The Panel has amended this factor to "energy source" to reflect the changing nature of technology used to produce electricity in the NEM. The Panel considers that the term "energy source" maintains the fundamental definition of the term fuel, while broadening the range of applicable technologies that are covered. For example, a potential provider may be able to specify a device that is capable of providing SRAS without a reliance on traditional fuels, and in this case the broader definition "energy source" would still apply. Therefore the Panel revised this requirement in the Draft Standard for fuel diversity as follows:

> "Energy source - diversity in the energy source or fuel utilised by services shall be considered to account for any single points of failure across the procured SRAS sources for each electrical sub-network."

As discussed in section 6.4 above, the Draft Standard now requires AEMO to consider diversity as part of its consideration of aggregate reliability of the SRAS sources procured for a given electrical sub-network. This gives AEMO the ability to consider the impact of fuel storage on the energy diversity of the SRAS sources as part of its SRAS Guideline.[150]

6.8.3 Link between diversity and aggregate reliability

The Panel recognises that the diversity requirements listed above relate to the aggregate reliability for restarting the electrical sub-networks. The diversity guidelines direct AEMO to consider points of failure that may impact a sub-network restoration. However, the Panel recognises that the current format of the Standard presents a conflict between AEMO's SRAS objective of minimising the procurement costs and while also considering the diversity requirements of the Standard[151]. The current Standard requires AEMO to "consider" the diversity elements, but it is not clear how AEMO should consider these elements, or how AEMO should justify spending more on SRAS in order to perform better against the diversity elements.

As the diversity elements are fundamentally related to the reliability of SRAS, at the sub-network level, in the Draft Standard the Panel has linked the diversity elements to the determination of aggregate reliability covered in section 5 of the Standard and discussed above in section 6.4.

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148 Reliability Panel, Review of the System Restart Standard, Final Determination, 2012, p.24.

149 AEMO submission to the Issues Paper, p.3.

150 Clause 3.11.7(d)(2) of the Rules

151 AEMO submission to the Issues Paper, p3

The Panel recognises that an additional burden is placed on AEMO by requiring it to consider diversity when assessing the aggregate reliability of an electrical sub-network. However, the Panel considers that this change reinforces the importance of the diversity guidelines within the Draft Standard and provides AEMO with improved clarity on how to treat diversity when applying the Draft Standard.

6.8.4 Strategic location of SRAS sources

The Standard is also required to include guidelines for strategic locations of SRAS sources.[152] The current Standard does not provide specific guidance on this.

The strategic location of SRAS is a key component in AEMO's SRAS procurement decision making process[153], and the Panel considers that AEMO is best positioned to determine the strategic locations of SRAS when selecting SRAS for each electrical sub-network. However, to provide clarity between the Standard and AEMO's SRAS Guidelines, the Draft Standard includes general guidelines on the strategic location of SRAS, while leaving the responsibility for selecting specific SRAS locations with AEMO. The Panel has included these guidelines as a separate section in the draft Standard, to avoid confusion with the diversity guidelines which are linked to the determination of aggregate reliability.

The guidelines for the strategic location of services in the Draft Standard are as follows:

> "AEMO shall determine the strategic location of SRAS, based on an assessment of how the geographical and electrical location of those services best facilitates the power system restoration. The locational value of SRAS relates to its ability to energise the transmission network and assist other generating units to restart. A strategic location for SRAS may be either within or outside the *electrical sub-network* for which the service is required.[154]"

The Panel considers that these guidelines provide AEMO with the appropriate guidance and flexibility to determine the strategic location of SRAS as part of their SRAS procurement function.

6.9 Arrangements for implementation of the Standard

The Terms of Reference fir this Review state that:

> "The Panel's review and determination of the Standard must be finalised in time to allow AEMO to amend the SRAS Guidelines, and to be used by AEMO for the next round of SRAS procurement. Accordingly, the Panel must complete its determination of the Standard no later than December 2016."

Therefore, to allow sufficient time for the AEMO to amend the SRAS Guidelines, the Panel proposes that the new System Restart Standard take effect on 1 July 2018.

152 Clause 8.8.3(aa)(7) of the Rules

153 AEMO, SRAS Guidelines, 2014, p16

154 Clause 8.8.3(aa)(5) of the Rules.

The Panel invites comment from stakeholders on this timing and necessary arrangements required for the implementation of the Standard.

7 Additional Recommendations

Throughout the process of reviewing the Draft Standard the Panel has become aware of a number of issues that are not within the scope of the review but do relate more generally to the processes for procuring SRAS and for restarting an electrical sub-network following a major supply disruption.

7.1 A review of the standards for sub-station batteries

The control and protection systems in electrical sub-stations operate from large dedicated battery systems. Under normal conditions these battery systems are continuously charged from the network connected to the sub-station, effectively providing an uninterruptible supply to the control and protection systems at the sub-station. This means that the control and protection systems at the sub-station can continue to operate during interruptions to the supply at the sub-station.

The battery system at a sub-station is designed to meet the load of the control and protection systems for a minimum period of time, typically 10 hours. However, in practice the performance of the battery systems deteriorates over time and often the loading on the batteries increases as additional equipment is installed at the substation, such as new communications and control or protection systems. Thus it is possible that a battery system will not remain operating as long as expected during a major supply disruption. If the battery systems go flat before the supply is restored remote control of the sub-station would no-longer be possible and staff would need to be sent to perform manual switching operations when the sub-station is eventually energised.

Given that the state of the battery systems in the affected sub-stations may become critical, especially if there is a delay in the restoration process, the Panel recommends that the owners of the major sub-stations in the NEM review the state of their battery systems to ensure that their performance is consistent with the requirements of the associate system restart plan and local black system procedures.

7.2 Importance of reliable communications networks

The restoration of the power system following a major supply disruption, particularly one that resulted in a black system condition, requires careful coordination between AEMO, the relevant TNSP and DNSPs, the generation and Jurisdictional System Security Coordinator in the affected electrical sub-network. This will require reliable communication networks throughout out this period.

In the absence of a major supply disruption the communications systems are generally reliable, with sufficient redundancy to manage outages of different components of the communications network. However, during a severe major supply disruption there may be a loss of electricity supply to communications networks, which then rely on emergency supplies such as batteries or standby generators, depending on the operator of the communications network. The Panel understands that in some cases the communications networks can only operate for less than a few hours before the emergency batteries supplies are flat.

Therefore, it is important AEMO and the stakeholders that perform aspects of the system restoration, identify any susceptibility of the communications networks to a loss of supply.

7.3 AEMO consultation with TNSPs during procurement process

The Panel is aware that some stakeholders consider that the current SRAS procured by AEMO does not comply with the current Standard. This means that other stakeholders may get a mixed message as to whether sufficient SRAS has been procured.

The Panel notes that the SRAS rule change recently introduced an amended clause 3.11.7(b):

> "*AEMO* must consult with the relevant Network Service Provider to identify and resolve issues in relation to the capability of any system restart ancillary service proposed to be provided by an SRAS Provider in an *electrical sub-network* to meet the *system restart standard*."

This requires AEMO to consult with the relevant network service provider to resolve any issues in relation to the capability of the individual SRAS sources. While this change will increase consultation on some limited aspects of SRAS, it is unlikely to address some of the concerns raised nor require any broader engagement with relevant stakeholders.

The Panel appreciates the various confidentiality obligations with which AEMO must comply when undertaking its procurement of SRAS, and that there is no obligation on AEMO to consult in relation to the level of SRAS to be procured. However, the Panel considers that there would be value in AEMO exploring avenues through which it might be able to increase engagement with key stakeholders, such as TNSPs, in relation to its consideration of key elements relevant to its procurement of SRAS. This could include what AEMO considers to be the technical limitations in the power system and the performance of the SRAS and the capability of the transmission network in light of these limitations.

7.4 Growing penetration of renewable generation

The Panel is aware that there is a growing penetration of renewable generation in the NEM, usually in the form of wind turbines and solar PV. These forms of generation do not use synchronous generating units but rely on non-synchronous units or inverters. In addition, the increased penetration of renewable generation, combined with reducing demand for electricity, has led to the several synchronous generators being de-commissioned.

AEMO and ElectraNet have been investigating the impact of the reducing amount of synchronous generation, particularly in South Australia.[155] AEMO and ElectraNet have identified a number of potential power system security issues, including the reduction in inertia that can lead to high rates of change of frequency and lower fault

155 AEMO and Electranet, Update to Renewable Energy Integration in South Australia – February 2016, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis.

levels that can have several impacts on the operation of the power system. AEMO's recently published Electricity Statement of Opportunities notes the potential implications of the reduced amount of synchronous generation on SRAS capability.

On 14 July 2016 the AEMC initiated a review into the market frameworks that affect system security in the NEM. The review follows and will be coordinated with ongoing technical work on these and related issues undertaken by AEMO. The terms of an agreement have been set out on how the AEMC and AEMO will collaborate, seeking to ensure that these activities deliver a coordinated package of measures to maintain future power system security. The terms of reference for this review can be found on the AEMC's website[156].

In addition, the AEMC has received a rule change request from AGL which relates to the subject matter of this review and seeks the introduction of an inertia ancillary services market. The AEMC has also received four rule changes from the South Australian government[157] in relation to the management of the power system security issues.

The Panel will monitor the progress of the various projects above and the potential implications for the System Restart Standard.

7.5 Enforcement of the System Restart Standard

The Panel is aware that some stakeholders are concerned whether the SRAS that has been procured is sufficient to meet the current Standard. The Panel's main obligation is in the setting of the Standard, not that sufficient SRAS is procured to meet the Standard. Under the current NEM arrangements, the ongoing compliance with the Standard is a matter for the AER.

7.6 Implication of AEMO amending the electrical sub-network boundaries

As discussed in section 6.5, the set-points in the Draft Standard are specific to the current boundaries of the electrical sub-networks. However, the Draft Standard includes guidelines for AEMO for setting the sub-network boundaries and this introduces the possibility that AEMO could, once the Standard is made, subsequently amend the electrical sub-network boundaries.

This possibility was raised in the AEMC's 2015 SRAS rule change and the Commission considered that "such interactions were manageable through existing processes."[158] Therefore, in accordance with the Rules, if AEMO did amend the sub-network boundaries then the Panel could do a limited review of the Standard for the affected electrical sub-network(s) to ensure the Standard is still appropriate for those amended or new sub networks.

156 http://www.aemc.gov.au/getattachment/b1f8c1e1-dcbe-4585-aa45-9152104fdcf2/Terms-of-reference.aspx.

157 Government of South Australia, Rule Change Requests, System Security, July 2016.

158 AEMC, System restart Ancillary Services rule change, 2015, p.70.

The Panel is seeking stakeholder views on this and will consider submitting to the AEMC a suitable rule change request, if appropriate, to address this issue

A The Draft System Restart Standard

1. Introduction

This System Restart Standard (standard) was determined by the Reliability Panel (Panel) in accordance with clauses 8.8.1(a)(1a) and 8.8.3 of the National Electricity Rules (Rules). The purpose of this standard is to provide guidance and set a benchmark to assist the Australian Energy Market Operator (AEMO) in procuring sufficient system restart ancillary services (SRAS) to meet the requirements of the National Electricity Market (NEM). This standard is effective from 1 July 2018.

2. Requirements of the standard

The requirements of the standard are specified in clause 8.8.3(aa) of the Rules, which states that (italicised terms are defined under the Rules):

"The system restart standard must:

1. be reviewed and determined by the *Reliability Panel* in accordance with the *SRAS Objective*;
2. identify the maximum amount of time within which *system restart ancillary services* are required to restore *supply* in an *electrical sub-network* to a specified level, under the assumption that *supply* (other than that provided under a *system restart ancillary services* agreement acquired by *AEMO* for that *electrical sub-network*) is not available from any neighbouring *electrical sub-network*;
3. include the aggregate required reliability of *system restart ancillary services* for each *electrical sub-network*;
4. apply equally across all regions, unless the Reliability Panel varies the system restart standard between electrical sub-networks to the extent necessary:

(a) to reflect any technical system limitations or requirements; or

(b) to reflect any specific economic circumstances in an *electrical sub-network*, including but not limited to the existence of one or more *sensitive loads*;

5. specify that a *system restart ancillary service* can only be acquired by *AEMO* under a s*ystem restart ancillary services* agreement for one *electrical sub-network* at any one time;
6. include guidelines to be followed by *AEMO* in determining *electrical sub-networks*, including the determination of the appropriate number of *electrical sub-networks* and the characteristics required within an *electrical sub-network* (such as the amount of *generation* or *load*, or electrical distance between *generation centres*, within an *electrical sub-network*); and
7. include guidelines specifying the diversity and strategic locations required of *system restart ancillary services*."

The Panel has detailed the factors that it considers in making its determination of the standard in its decision, "AEMC Reliability Panel 2016, System Restart Standard, Draft Report, 25 August 2016". This draft determination explains how the Panel has reviewed and determined the standard in accordance with the SRAS objective. The Panel's decision with respect to the other requirements of the standard in clause 8.8.3(aa) are outlined below.

3. Restoration timeframe

For each electrical sub-network, AEMO shall procure SRAS sufficient to, following a major supply disruption, restore generation and transmission in that electrical sub-network such that supply[159] in that electrical sub-network is restored to the level set out in column 2 of Table 1 within the restoration time set out in column 3 of Table A.1.

The restoration timeframe represents the 'target time-frame' to be used by AEMO in the SRAS procurement process. It is not a specification of any operational requirement that should be achieved in the event of a major supply disruption.

4. Aggregate reliability of SRAS

Aggregate reliability is the probability that the generation and transmission in a sub-network is expected to be restored to the specified level within the specified time. For each electrical sub-network, the required aggregate reliability shall meet or exceed the values shown in column 4 of Table A.1.

The reliability of any individual SRAS will incorporate the expected start-up performance and availability of that service.

The aggregate reliability of the procured SRAS in each electrical sub-network shall be determined by AEMO, considering the combination of the individual reliabilities of the SRAS procured in that electrical sub-network, together with an assessment of the impact of the points of failure set out in the guidelines for diversity in section 8 of the standard.

AEMO will determine the manner in which reliability will be assessed in accordance with the requirements in the Rules.

5. Applicability of the standard in electrical sub-networks

This standard shall apply equally across all regions and electrical sub-networks, except as varied between electrical sub networks in Table 1 and set out below.

In addition, for the New South Wales electrical sub-network AEMO shall procure SRAS sufficient to also:

- re-supply and energise the auxiliaries of at least 500 MW of generation capacity north of Sydney within 1.5 hours of a major supply disruption with an aggregate reliability of at least 75%.

6. Use of SRAS in neighbouring electrical sub-networks

A system restart ancillary service can only be acquired by AEMO under a system restart ancillary services agreement for one electrical sub-network at any one time.

159 Supply is defined in chapter 10 of the Rules as "the delivery of electricity"

7. Guidelines for the determination of electrical sub-networks

AEMO shall determine the boundaries for electrical sub-networks without limitation by taking into account the following factors:

- the number and strength of transmission corridors connecting an area to the remainder of the power system;
- the electrical distance (length of transmission lines) between generation centres; and
- an electrical sub-network should be capable of being maintained in a satisfactory operating state to the extent practicable during the restoration process, and in a secure operating state from a stage in the restoration when it is practicable to do so, as determined by AEMO.

8. Guidelines for assessing the diversity of services

In determining the aggregate reliability of SRAS in an electrical sub-network, AEMO shall consider diversity of the services by taking into account the following guidelines:

- Electrical - diversity in the electrical characteristics shall be considered particularly with respect to whether there would be any single points of electrical or physical failure across the procured SRAS sources for each electrical sub-network;
- Geographical - diversity in geography shall be considered with respect to whether there would be any single points of failure related to the potential impact of geographical events such as natural disasters; and
- Energy Source - diversity in the energy source or fuel utilised by services shall be considered to account for any single points of failure across the procured SRAS sources for each electrical sub-network.

9. Guidelines for the strategic location of services

AEMO shall determine the strategic location of SRAS based on an assessment of how the geographical and electrical location of those services best facilitates the power system restoration. The locational value of SRAS relates to its ability to energise the transmission network and assist other generating units to restart. A strategic location for an SRAS may be either within or outside the electrical sub-network for which the service is procured.

Table A.1 Time, Level and Aggregate Reliability by Electrical Sub-Network

1. Electrical Sub-Network[160]	2. Level of Restoration (% of Average Operational Demand[161])	3. Restoration time (hrs)	4. Aggregate Reliability
North Queensland	45%	4.0	90%
South Queensland	25%	3.0	90%
New South Wales	20%	3.0	90%
Victoria	20%	3.0	90%
South Australia	25%	3.0	90%
Tasmania	30%	3.0	90%

160 The electrical sub-network boundaries are defined in the AEMOs 2014 SRAS Guideline.

161 Operational Demand in a region is demand that is met by local scheduled generating units, semi-scheduled generating units, and non-scheduled intermittent generating units of aggregate capacity ≥ 30 MW, and by generation imports to the region. It excludes the demand met by non-scheduled non-intermittent generating units, non-scheduled intermittent generating units of aggregate capacity < 30 MW, exempt generation (e.g. rooftop solar, gas tri-generation, very small wind farms, etc), and demand of local scheduled loads.

B Issues Summary

Stakeholder	Issue/Comment	Reliability Panel Response
AEMO	• AEMO considers that the current form of the Standard, driving the procurement of services rather than setting operational obligations, is practical and appropriate.	• The Draft standard is set as a procurement standard, ref section 2.4.
	• The Standard should be clear. The Panel could also consider adding a level of specification around the role of modelling or testing in qualifying a SRAS, and the power system conditions to be assumed by AEMO in the procurement process. Improvements such as these would support a common interpretation of the Standard by AEMO and potential SRAS providers.	• The Panel has sought to clarify the Standard as is appropriate. However, the Panel has not included any specific guidance on the role of testing or modelling in qualifying SRAS.
	• AEMO is required to meet the SRAS Procurement Objective which is to use reasonable endeavours to acquire SRAS to meet the Standard at the lowest cost. This obligation is clear, however, when this obligation is qualified by expectations on diversity or redundancy, it risks losing its clarity, and will increase the cost of procuring SRAS.	• This is discussed in section 6.4.3.
	• If the Panel wanted diversity and/or redundancy in SRAS, then clarity is needed in relation to this requirement rather than a requirement to “consider” it, which is clearly open to different interpretations. In this case, clarity in the requirements would help align the procurement outcomes to the SRAS Procurement Objective.	• This is discussed in section 6.4.3.
	• In its review of the Standard and setting parameters and requirements for the time and level of restoration, number of services and regional variation, the Panel needs to consider the incremental technical and economic benefits provided compared to the additional costs.	• This is addressed in the economic assessment, discussed in Chapter 5.
	• It is preferable that restoration be focused on outcomes rather than intermediate steps. Having a Standard with temporal targets for both the intermediate step of restoring auxiliaries of generating units and the availability of sufficient generating capacity does not provide any benefits in the procurement process.	• The intermediate step has been removed as a general requirement. This is discussed in section 6.3.4.
	• The Panel may wish to assess whether the four-hour timeframe is still the most appropriate. The current specifications were	• The draft Standard includes new set-points for each

Stakeholder	Issue/Comment	Reliability Panel Response
	determined a number of years ago, and the technical characteristics of the power system are now changing due to the continually changing generation mix.	sub-network based on AEMO advice.
	• It is not realistic for the level of restoration to consider individual loads. Not only would doing so potentially result in higher costs of procurement for other customers but those costs may be inefficient because of the more limited opportunities to mitigate outage risks available to AEMO compared to the customer.	• The Panel agrees. This is discussed in section 6.3.5 with respect to sensitive loads.
	• Any redundancy requirement that is imposed as part of the Standard has the potential to materially increase the overall cost of SRAS procured, and the benefits of the potential cost increase should be identifiable.	• This is included in the determination of aggregate reliability, discussed in section 6.4.3.
	• There is no reason why the Standard could not be different in different regions, particularly as the recent Rule Change stipulates the recovery of costs to be on a regional basis.	• The Draft Standard is tailored to each specific electrical sub-network.
ENA	• When reviewing the Standard, consideration will need to be given to ensuring supply to sensitive loads (smelters) and other critical loads (city precincts, LNG processing plant etc.) is restored expeditiously within each sub-network taking account of network and generation constraints within that sub-network.	• Sensitive loads are discussed in section 6.3.5. The restoration of specific loads like city precincts etc is managed by the NSP's local black start procedures.
	• When setting targets for the Standard, modelling of total system performance will need to be undertaken, including flows from adjacent sub-networks(notwithstanding the requirement that services will need to be sourced within each sub-network.	• The review incorporated power system modelling results provided by AEMO and discussed in section 4.2. The restoration of each sub-network is treated in isolation as per Clause 8.8.3(aa)(2) of the Rules.
ERM Power	• The probability of a major supply disruption is low, but such events do occur.	• The Panel agrees.
	• SRAS is like an insurance policy, however unlike insurance there are no alternatives.	• Noted.
	• The length of procurement contracts are too short to recover capital and this presents a barrier for new entrants.	• The 2015 SRAS Rule change increased SRAS procurement options.
	• AEMO should not have power of direction after restoration as a direction notice will require	• This is beyond the

Stakeholder	Issue/Comment	Reliability Panel Response
	stakeholders to switch emphasis from resolving the issue to recording actions for future legal actions.	scope of this review.
	• The Reliability Panel should commission independent audits of AEMO SRAS procurement.	• This is discussed in section 7.5.
	• Panel should examine a requirement for adequate communication capability between parties.	• This is discussed in section 7.2.
	• AEMO should be required to take into account info from Generators and TNSPs.	• This is discussed in section 7.3.
	• Panel should take into account the restoration timelines in Australia and overseas.	• This is discussed in section 4.2.
	• Current Standard does not set out restoration of supply for end consumers. Revised Standard should be transparent on this point, with restoration <100% of peak demand after a certain period.	• The Draft Standard does not specify a time to restore load. This is discussed in to section 6.3.3.
	• A generator takes time to be re-sychronise. The existing Standard relating to "available" doesn't take into account generators lack of ability to step change and need to ramp up.	• The generators' "ramp-up" capability is taken into account in the AEMO technical advice. This is discussed in section 4.2.
	• After a major supply disruption, the network will be unstable. AEMO should be required to take into account the following: — ramping time; — generation mortality rate in unstable environment; and — time required for DNSP and TNSP to restore load	• Generator ramp-up time is considered in AEMO modelling; generator mortality is not considered. This is discussed in section 6.3.3 regarding restoration of load.
	• SRAS should be used to restore load blocks, so that when generators are ramped up, there is load available. Restoring load blocks along with auxiliaries will reduce time of restoration.	• The Standard is focused on restoration of generation and transmission. This is discussed in section 6.3.3.
	• A certain percentage of 50% probability of exceedance (POE) peak demand load should be restored within a certain timeframe. For example, 80% of load restored with the 24 hour period.	• This is discussed in section 6.3.3 regarding restoration of load.
	• Standard should set out restoration within 1.5 hours of auxiliaries of 60% of scheduled	• The intermediate step has been removed.

Stakeholder	Issue/Comment	Reliability Panel Response
	generators in a sub-network.	This is discussed in section 6.3.4
	• Reliability level should be close to 100%. This implies there will almost always be SRAS to respond to concerns.	• This aligns with the Panels approach to risk management. This is discussed in section 6.2.2
	• Note that requiring a minimum number of services per sub-network would improve transparency for governments and consumers.	• Section 6.4.2 addresses the determination of aggregate reliability.
	• Governments and TNSPs are best placed to discuss individual issues relating to the characteristics of electrical sub-networks.	• The Panel consulted with the regional JSSC's. This is discussed in section 1.4.
	• Could include maximum length of electrical distance between generation centres - generators could be physically near SRAS but electrically distant.	• Electrical distance is a guideline for setting sub-network boundaries. This is discussed in section 6.7.
	• There should be a maximum load allowed in each sub-network.	• The Panel does not consider this is relevant to the setting of boundaries for electrical sub-networks.
	• The Existing diversity guidelines are appropriate.	• Noted.
GDF Suez	• GDFSAE supports the Standard retaining this intermediate step to provide AEMO and potential SRAS providers a more transparent framework within which to procure and utilise system restart services.	• The intermediate step has been removed. This is discussed in section 6.3.4.
	• GDFSAE believes that the requirement for AEMO to establish a defined amount of generation and transmission capacity within a set time frame is an appropriate form for the Standard, which also enables jurisdictions to assess consumers' satisfaction with the Standard and its risks.	• The time and level element is maintained in the Draft Standard. This is discussed in section 6.3.
	• GDFSAE suggested that the Reliability Panel give consideration as to whether the existing metrics of 4 hours and 40 per cent of peak demand remain appropriate.	• The Draft Standard has been determined based on current technical advice and economic analysis.
	• Consideration should also be given to whether	• The level of restoration

Stakeholder	Issue/Comment	Reliability Panel Response
	the peak demand measure remains appropriate. Recent growth in non-scheduled generation (e.g. solar, small scale wind, etc.) has led to a need to re-consider what is intended by the word “demand”. AEMO more commonly refer to “Operational Demand”, which is the amount of customer load that is met by scheduled and semi-scheduled generators in the NEM.	in the Draft Standard, is relative to average operational demand. This is discussed in section 6.3.3.
	• To ensure that an adequate and transparent quantity and quality of system restart service is obtained for each sub-network, it is important that a well-defined aggregate reliability is defined by the Reliability Panel. An aggregate reliability could be inputs based standard or outcomes based. GDFSAE supports an output based standard. The most direct way to achieve this would be to assign levels of confidence to be maintained for the time taken, and level of restoration.	• The aggregate reliability in the Draft Standard is "outcomes based". This is discussed in to section 6.4.
	• As an added measure to provide confidence that the aggregate reliability level is being maintained appropriately, the Reliability Panel could periodically arrange for an independent review of the AEMO modelling and results.	• Noted. This is discussed in section 7.5
	• GDFSAE is of the view that with the Standard expressed in terms of confidence levels as suggested above, there is less need for the Reliability Panel to consider the relative complexity of one region compared to another. These matters would need to be considered by AEMO in ensuring that it is able to meet the aggregate reliability standard.	• The Panel has determined the Draft Standard on the basis of specific analysis for each electrical sub-network.
	• GDFSAE believes that the guidelines for sub-networks are reasonable, however it has been difficult in the past for industry stakeholders to understand exactly how these factors have been applied by AEMO in their decision processes. GDFSAE therefore suggests that a new obligation should be included in the system restart standard that requires AEMO to publish the method in which they applied the factors, and how they have determined the sub-network boundaries.	• Noted. This issue relates to the Rules and was addressed in the 2015 SRAS Rule Change.
	• GDFSAE believes that the current requirements for diversity of system restart sources are adequate. Introducing the probabilistic approach to the aggregate reliability standard would provide further impetus for AEMO to consider diversity of its proposed system restart sources.	• Noted. This is discussed in section 6.8.

Stakeholder	Issue/Comment	Reliability Panel Response
Hydro Tasmania	• The current SRAS procurement in Tasmania of 1 unit at 90% reliability (or availability), leaves Tasmania potentially without SRAS for 10% of the time.	• Noted. The Draft Standard includes a new aggregate reliability requirement. This is discussed in section 6.4.
	• Hydro Tasmania requested the inclusion of requirements for priority restoration of sensitive loads, such as nominated restoration times for sensitive loads.	• This is discussed in section 6.3.5.
	• Hydro Tasmania suggested that the vulnerability of the SRAS source to transmission corridor damage be assessed in determining the reliability of that source.	• Noted. This is discussed in section 6.4.3.
	• Hydro Tasmania expressed a view that the Tasmania power system would benefit from a minimum of 2 SRAS sources with appropriate diversity. More generally an n-1 or n-2 approach to redundancy may be beneficial.	• Noted. The Draft Standard includes a new aggregate reliability requirement. This is discussed in section 6.4.
	• Assessment of time component of SRS should include allowance for time to restart thermal generation after outage and the social dependence on continuity of electricity supply.	• Noted. This is incorporated in the economic assessment.
	• Hydro Tasmania recommends that where there is a single SRAS source, The required aggregate reliability should be much higher than 90%.	• Noted.
	• Hydro Tasmania recommend that Tasmania would best be served by the definition of two electrical sub-networks, due to the vulnerability of major transmission lines linking the north and south of the state.	• The Draft Standard includes a new aggregate reliability requirement. This is discussed in section 6.7.
Major Energy Users (MEU)	• SRAS is only used for a black system, where restoration from neighbouring regions is not available. This is very low probability.	• The Panel has taken this into account in this draft determination.
	• Generators should pay all SRAS costs due to the potential for gaming the system to increase prices where there isn't competition.	• This is out of scope for this review.
	• The Issues Paper implies that the existing Standard is largely correct and that any changes will be minor alterations- this is not appropriate, the MEU supports an in depth review of the Standard and settings.	• The Panel has undertaken an "in-depth" review of the Standard.
	• Some relaxation of the Standard, to represent the low probability of an event, would help to	• The economic assessment

Stakeholder	Issue/Comment	Reliability Panel Response
	reduce SRAS costs.	considered the probability of a black system event.
	• Work on upgrading sub-network interconnectors would help to prevent cascading cross-region events.	• Noted, this is a concern related to system security.
	• It would be appropriate to imposing all the commercial obligations for SRAS on generators, as they are the primary beneficiary of the service, as it enables them to restart production.	• This is out of scope for this review. (addressed in the 2015 SRAS rule change).
	• The VCR should be the basis for estimating the cost of major supply disruption.	• VCR was used in the economic assessment.
	• The MEU note that there is no "science" in the timelines outlined in the Standard.	• The draft standard is based on a probabilistic economic assessment.
	• The Standard should be set so that the long term unserved energy due to major supply disruption is 0.002% - ie the reliability standard.	• The standard is part of a broader governance framework for mitigating risk of major supply disruptions. This is discussed in section 2.1
	• Considers that the requiring a minimum number of services is akin to insuring twice.	• Noted. This is considered in the setting of aggregate reliability.
	• AEMO should supply technical information to the Panel on the appropriate way to address the concerns relating to system restoration, and this advice should be made public.	• AEMO supplied technical advice. This is discussed in section 4.2.
Russel Skelton & Associates	• The Standard should define the time and level of restoration for load, not just "supply".	• The Standard defines a target for restoration of supply. This is discussed in section 2.1.6.
	• The Standard should vary across sub-regions to account for regional differences.	• The Draft Standard varies between sub-networks.
	• Sub-networks should be determined on the economic characteristics of the load within the region, including consideration of sensitive loads, with technical network characteristics a secondary consideration.	• The Panel's consideration on the guidelines for sub-network boundaries is covered in section 6.7.

Stakeholder	Issue/Comment	Reliability Panel Response
	• A real world outage is likely to involve events that act to reduce the reliability of the SRAS service including plant damage, staff availability and impaired communications.	• Noted. This is discussed in section 2.1.5.
	• A real world system outage could present significant challenges to the operation of trip to house load (TTHL) SRAS, with real world success rates for TTHL less than 50%.	• The application of aggregate reliability is discussed in section 6.4.2 .
	• The ability to restart the network from multiple sources in different location provides the possibility of reduce restoration time and redundancy in the event of network or generator failure.	• This is incorporated into the economic assessment, as discussed in section 5.1.1.
	• Reliability of SRAS should account for not just SRAS operation but also restoration of load.	• The Standard defines a target for restoration of supply. refer to section 2.1.6.
	• Current arrangements do not take into account the risk of restart not going to plan for black start generators, secondary generators, networks and operation systems.	• This is considered in the economic assessment. This is discussed in section 5.2 & 6.2.
	• AEMO should be required to provide more transparency on implementation of the Standard.	• Noted. This is discussed in section 7.5.
	• The increased level of renewable generation and corresponding drop in traditional synchronous generation will lead to an increased risk of outage.	• Noted, while this is contextual, it is mainly a system security issue.
	• Restart plans need to be flexible and resilient enough to deal with network damage, assumption of 100% network availability is "absurd".	• This is discussed in section 5.2.2.
	• The total impact of a major supply disruption is likely to exceed the direct cost of unserved energy, indirect flow on and social costs should be considered.	• The economic assessment considers indirect and social costs.
	• Current arrangements do not give stakeholders clarity on expected service restoration time in the event of a black system event - this should change to give stakeholder access to such information to assist with decision making and planning.	• This is discussed in section 6.3.3.
	• The Standard should be determined on the basis of an economic trade-off between costs of SRAS and benefits due to reduction in	• The Panel agrees. This is discussed in Chapter 5.

Stakeholder	Issue/Comment	Reliability Panel Response
	restoration time.	
	• The economic assessment process may benefit from a pragmatic approach, such as considering upper and lower bounds for each variable part of a wider sensitivity analysis.	• The economic assessment included upper and lower bounds to account for uncertainty.
	• AEMO's VCR is likely to be the best available estimate of the consumers' willingness to pay for SRAS.	• The economic assessment utilised AEMO's VCR.
SACOSS	• AEMO must be incentivised throughout the Standard to ensure that not only procurement standards are met but that TNSP and generator black start plans are in a state of readiness, including maintenance and adherence to performance standards, so as to minimise the restoration time in line with a standard.	• The broader governance arrangements are discussed in section 2.2.
	• SACOSS support a sub-network specific consideration of the system restart standard given the unique generation plant in SA.	• The Draft Standard set-points are tailored to each specific sub-network.
	• All actions, standards and performance metrics should be geared towards minimising the time to complete restoration.	• Chapter 3 discusses the Panels assessment framework.
	• Noting the drop in SRAS expenditure from $55m to $21m between 2014/15 and 2015/16, SACOSS is concerned that there has been a substantial change in the level of SRAS capability. It is possible the reduction in annual expenditure is outweighed by an increased exposure to costly issues associated with delays in restoration from a major supply disruption.	• The Panel considers that the Draft Standard strikes an appropriate balance that is consistent with the SRAS Objective and the NEO.
Snowy Hydro	• The primary focus of AEMO 2015 procurement was immediate cost, not total economic benefit.	• This is consistent with the SRAS Objective for procurement.
	• The fact that there has only been one black system event in the NEM since market start does not mean that this historical level of performance would continue into the future.	• Noted. this is covered in section 5.1.1.
	• AEMO’s power system modelling and studies for assessing black start generators do not provide sufficient detail for market participants and other stakeholders to determine whether AEMO has acquired sufficient SRAS.	• This is discussed in section 7.5.
	• There should be an efficient level of SRAS procured to minimise the total expected cost of	• Agreed. This is discussed in Chapter

Stakeholder	Issue/Comment	Reliability Panel Response
	an outage and immediate costs of SRAS.	3.
	• The ROAM analysis of probability of outage, coupled with VCR could be used to determine whether efficient levels of SRAS have been purchased.	• This is covered by the economic assessment described in Chapter 5.
	• Current Standard level is appropriate, however inappropriate analysis of practical issues by AEMO before procuring SRAS. Usage of "Goldilocks sets of scenarios". By relying on desktop studies with assumptions of 100% reliability and no operational difficulty is restoring load.	• These assumptions are discussed in section 5.2.2.
Stanwell	• Recent procurement of SRAS by AEMO over-prioritised short term costs. This has left the system considerably less "insured" against an outage compared to previous periods.	• The Panel's draft standard sets an appropriate level of coverage, supported by the economic assessment. This is discussed in chapter 3.
	• In the event of a major supply disruption the marginal benefit of extra SRAS is likely considerable, even if probability of it being needed is low.	• The economic assessment balances the probabilistic benefits of SRAS against the costs.
	• VCR is only the direct cost of an outage, other indirect costs should also be considered.	• The economic assessment report discusses direct and indirect costs.
	• Stanwell considers the objective is better defined as the annualised-risk cost of procuring SRAS.	• Noted. This is discussed in chapter 5.
	• Increase penetration of renewables means SRAS more important than ever, especially at the edge of network.	• Noted.
	• Stanwell understands that at least two unsuccessful SRAS vendors are disabling their SRAS capability. The SRS needs to consider incentives for long term supply of SRAS.	• This difference in objectives is clearly defined in the Rules.
	• Panel assess against the SRAS Objective while AEMO work to the SRAS Procurement Objective. Stanwell note the different emphasis of these objectives.	• Noted.
	• The cost of a major supply disruption is determined by the volume of affected load, value of affected load and the duration. Only the duration is impacted by the provision of	• This is accounted for in the economic assessment. This is discussed in sections

Stakeholder	Issue/Comment	Reliability Panel Response
	SRAS.	4.3.1 & 5.1.
	• The impact of an outage increases in a non-linear matter over time. due to the impact on load, but also restoration timeline of generators.	• This is accounted for in the economic assessment, This is discussed in sections 4.3.1 & 5.1.
	• For confidence of generators and consumers, reliability should be near 100%.	• Section 6.4 discusses the appropriate determination of aggregate reliability of SRAS.
	• Sub-networks could be defined to include a certain value of unserved demand for a notional outage length. Based on the composition of the region and AEMO's VCR results for different categories of consumers.	• The guidelines for the definition of sub-network boundaries are discussed in section 6.7.
	• Stanwell support the retention of the current diversity requirements.	• Noted.
TransGrid	• TransGrid considers that the existing timeframes in the Standard are appropriate.	• Noted. Refer to chapter 6.
	• TransGrid has concerns with the ability of the existing SRAS to restore generation/transmission capacity equivalent to 40 per cent of peak demand in the sub-network as these services may not be able to fully achieve the requirements of the Standard.	• This is discussed in section 7.5
	• The Panel should give consideration to whether the Standard should outline expectations for restoration of sensitive and critical loads within the appropriate timeframe.	• Noted. This has been discussed in section 6.4.3.
	• A black system event is most likely to occur during system peak load and low generation availability (as this is when the risk to system security is greatest), therefore using peak load as a reference restoration level is appropriate.	• The Draft Standard level is set relative to average operational demand. This is discussed in section 6.3.3.
	• The Panel should also consider the economic and social impact of sensitive and critical loads and whether the level of restoration should place higher priority on these loads than others.	• This is covered in the economic assessment and discussed in section 7.5
	• The intermediate step has been removed. This is discussed in section 6.3.4	• The intermediate step has been removed. This is discussed in section 6.3.4

Stakeholder	Issue/Comment	Reliability Panel Response
	• TransGrid considers that it would be appropriate to include a minimum number of services for each sub-network. One suggestion is that this could be one more SRAS than what is required to satisfy the SRS according to AEMO's assessment.	• Noted. This has been addressed in new aggregate reliability requirement. This is discussed in section 6.4.
	• The Panel should give consideration to the technical limitations of the transmission system on a regional basis.	• Noted. This is inherent in the existing Standard and Rules, Section 7.3 covers the Panels comments on improved consultation.
	• AEMO define only one sub-network for NSW, however, there are two natural sub-networks in NSW, characterised by slow restart sources in the north and fast restart sources in the south which are constrained by physical limitations of the network to the major load centre in the Sydney area and supply to sensitive loads	• Section 6.5.7 covers how the Standard addresses, the special characteristics of the NSW sub-network.
	• The existing diversity requirements in the Standard are appropriate. The implementation of these diversity requirements should also be demonstrated during the procurement of SRAS.	• This has been addressed in section 6.8.3.
	• The Panel should consider:	
	— maintaining system security during restoration - including that the approach for ensuring system security during the restoration needs to be clear and explicit,	• The maintenance of system security is covered by the Rules and AEMO's operational procedures.
	— implementation of the regional network restoration plans - including the need for meaningful and timely consultation with the TNSPs to review and revise the regional network restoration plans, and	• This concern is discussed in section 7.3.
	— transition from one SRAS process to another - including that sufficient time is allowed for the revision of the plans, procedures and training of operating staff prior to any	• This concern is discussed in section 7.3.

Stakeholder	Issue/Comment	Reliability Panel Response
	change of the SRAS providers.	

C Terms of Reference

Review of the System Restart Standard

AEMC Terms of Reference to the Reliability Panel

30 June 2015

Introduction

These terms of reference are intended to guide the Reliability Panel (the Panel) in developing the System Restart Standard (the Standard).

As set out in clause 8.8.3(aa) of the National Electricity Rules (NER), the Australian Energy Market Commission (AEMC) requests that the Panel undertake a review of the Standard. The purpose, scope and timing for this review are set out below in these Terms of Reference. If there are any inconsistencies between the NER requirements and these Terms of Reference, the NER takes precedence.

Background

In the event of a major supply disruption, System Restart Ancillary Services (SRAS or restart services) may be used to supply sufficient energy to restart power stations in order to begin the process of restoring the power system.

The Panel is responsible for determining the Standard, which sets out several key parameters for system restoration, including the speed of restoration, how much supply is to be restored and the level of reliability of SRAS. The Australian Energy Market Operator (AEMO) then procures restart services to meet the Standard, and develops the System Restart Plan in accordance with the Standard.

On 2 April 2015, the AEMC published a final rule that made a number of changes to the SRAS frameworks in the National Electricity Market. The Reliability Panel is required by the final rule to revise the System Restart Standard as soon as practicable after the commencement of the final rule (1 July 2015), to take into account those changes.

The Panel's review and determination of the Standard must be finalised in time to allow AEMO to amend the SRAS Guidelines, and to be used by AEMO for the next round of SRAS procurement. Accordingly, the Panel must complete its determination of the Standard no later than December 2016.

Scope of this Review

When determining the Standard, the Panel must consider whether all of the relevant requirements in the NER have been met.[162] These NER requirements are described below.

In accordance with clause 8.8.3(aa)(1) of the NER, the Reliability Panel must review and determine the SRS in accordance with the SRAS Objective.

The SRAS Objective is defined in Chapter 10 of the NER as:

> "The objective for system restart ancillary services is to minimise the expected costs of a major supply disruption to the extent appropriate, having regard to the national electricity objective."

Clauses 8.8.3(aa)(2) to (7) of the NER state that the system restart standard must:

(2) identify the maximum amount of time within which system restart ancillary services are required to restore supply in an electrical sub-network to a specified level, under the assumption that supply (other than that provided under a system restart ancillary services agreement acquired by AEMO for that electrical sub-network) is not available from any neighbouring electrical sub-network;

(3) include the aggregate required reliability of system restart ancillary services for each electrical sub-network;

(4) apply equally across all regions, unless the Reliability Panel varies the system restart standard between electrical sub-networks to the extent necessary:

   (a) to reflect any technical limitations or requirements of the power system in the electrical sub-network; or

   (b) to reflect any specific economic circumstances in an electrical sub-network, including but not limited to the existence of one or more sensitive loads.

(5) specify that a system restart ancillary service can only be acquired by AEMO under a system restart ancillary services agreement for one electrical sub-network at any one time;

(6) include guidelines to be followed by AEMO in determining electrical sub-networks, including the determination of the appropriate number of electrical sub-networks and the characteristics required within an electrical sub-network (such as the amount of generation or load, or electrical distance between generation centres, within an electrical sub-network); and

(7) include guidelines specifying the diversity and strategic locations required of system restart ancillary services.

162 For the avoidance of doubt, any reference here to "the NER" refers to the new version of the NER that will commence 1 July 2015 and which will include the changes to the SRAS frameworks made in the final rule.

Considerations

In addition to meeting the above requirements which are set out in the NER, the Reliability Panel should also have regard to a number of additional matters when determining the Standard. These should include, but are not limited to, the following:

- The value of system restoration to consumers following a major supply disruption, including having regard to measures such as the value of customer reliability determined by AEMO; and
- The estimated costs of sourcing restart services.

Consultation

Stakeholder engagement will be central to the effective development of the Standard. The Panel should consult with as wide a range of stakeholders as possible, including network service providers, generators, consumers, jurisdictional governments and any other relevant bodies.

The Panel should also consider whether holding public forums and/or workshops may be helpful in facilitating more effective engagement with stakeholders.

Timing and deliverables

The Panel must carry out the review to develop the Standard in accordance with the following process:

- Give notice to all registered participants of commencement of this review and invite submissions for a period of at least four weeks.
- Publish an issues paper for consultation with stakeholders at the time of notifying stakeholders of the review. This paper should outline the key issues and questions the Panel will consider when determining the Standard.
- Publish a draft report and invite submissions for a period of at least six weeks.
- At the time of publishing the draft report, notify stakeholders that they may request a public meeting on the draft report within five business days of the draft report being published.
- If stakeholders have requested a public meeting, notify stakeholders that a public meeting will be held. At least two weeks' notice of the public meeting must be given.
- Publish a final report and submit this report to the AEMC no later than six weeks after the period for consultation on the draft report has closed.

As noted above, the Panel must complete its determination of the Standard no later than December 2016.

D Rules requirements for the system restart standard

Clause 8.8.3(aa) of the National Electricity Rules requires that the system restart standard must:

"(1) be reviewed and determined by the Reliability Panel in accordance with the SRAS Objective;

(2) identify the maximum amount of time within which system restart ancillary services are required to restore supply in an electrical sub-network to a specified level, under the assumption that supply (other than that provided under a system restart ancillary services agreement acquired by AEMO for that electrical sub-network) is not available from any neighbouring electrical sub-network;

(3) include the aggregate required reliability of system restart ancillary services for each electrical sub-network;

(4) apply equally across all regions, unless the Reliability Panel varies the system restart standard between electrical sub-networks to the extent necessary:

(A) to reflect any technical limitations or requirements of the power system in the electrical sub-network; or

(B) to reflect any specific economic circumstances in an electrical sub-network, including but not limited to the existence of one or more sensitive loads.

(5) specify that a system restart ancillary service can only be acquired by AEMO under a system restart ancillary services agreement for one electrical sub-network at any one time;

(6) include guidelines to be followed by AEMO in determining electrical sub-networks, including the determination of the appropriate number of electrical sub-networks and the characteristics required within an electrical sub-network (such as the amount of generation or load, or electrical distance between generation centres, within an electrical sub-network); and

(7) include guidelines specifying the diversity and strategic locations required of system restart ancillary services."

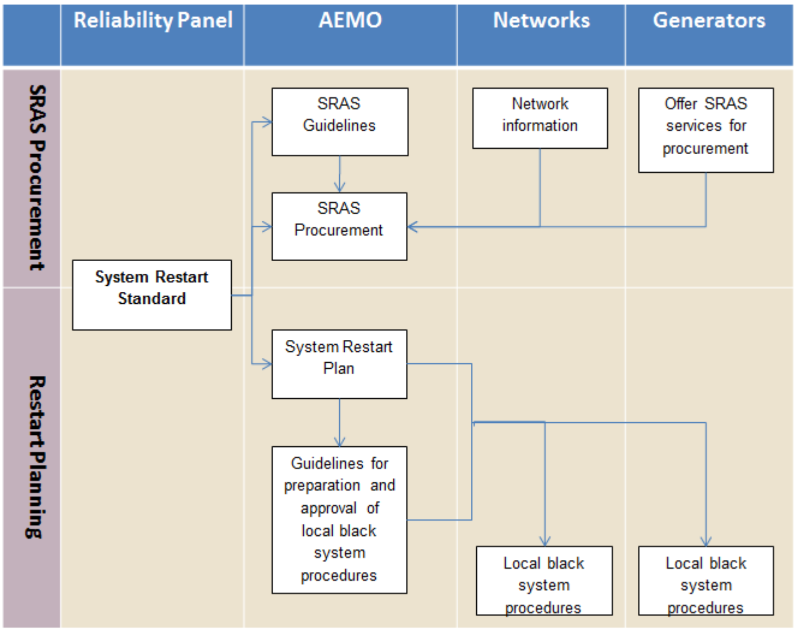
E Governance arrangements for managing major supply disruptions

This section describes the overarching policy framework for preparing for a major supply disruption under the NER, including statutory roles and responsibilities of the Reliability Panel, AEMO, Network Service Providers and Generators. This section also discusses the different associated documentation including the System Restart Standard, SRAS Guidelines and Restart Plans.

Preparing for a Major Supply Disruption

The Rules place obligations on various parties to establish the capability to be able to restart the power system following a major supply disruption. Specific parties that have key roles in determining system restart service provision include the Panel, AEMO, networks, and generators. A graphical representation of these responsibilities is laid out in Figure E.1.

Figure E.1 Responsibilities of parties in preparing for a major supply disruption



Reliability Panel

The Panel is responsible for reviewing and determining the System Restart Standard (the Standard).

Under clause 8.8.3(aa) of the Rules, the Panel must review the Standard in accordance with the SRAS Objective.[163] The Standard must contain several parameters for the restoration of the power system following a major supply disruption, including the maximum amount of time in which a specified level of supply must be restored in each sub-network, and the aggregate level of reliability of restart services in each sub-network.

163 The SRAS Objective is defined in the Rules, as outlined in Chapter 3.

As shown in Figure E.1, the Standard is the basis of AEMO's procurement of SRAS, and also informs the System Restart Plan. In determining the Standard, the Panel is ultimately driven by meeting the SRAS Objective and the NEO, specifically the restoration of a safe, secure and reliable power system. However, in order to achieve this, the initial focus of the Standard is to facilitate the restoration of the transmission systems and generation to a stable condition. This enables supply to be restored and for consumers subsequently to be brought on line.

For example, the current Standard requires AEMO to procure sufficient SRAS to "restore generation and transmission such that 40 per cent of peak demand in that sub-network could be supplied within four hours of a major supply disruption occurring." This is not a requirement that AEMO procure SRAS so that 40 per cent of peak demand from customers is re-supplied within four hours. Rather, it is a requirement that AEMO procure sufficient SRAS to enable the safe and secure operation of a level of generation capacity equivalent to 40 per cent of peak demand by the fourth hour after a major supply disruption.

As discussed below, it is the responsibility of network operators to restore power to individual consumers, in accordance with their local black system procedures and instructions from AEMO. Restoration of supply to consumers may not occur until a number of hours after the restoration of capability for generators as contemplated in the Standard.

AEMO

AEMO's responsibilities are established in the Rules, subject to the relevant guidance included in the Standard. This includes the development of the SRAS Guidelines.[164] These SRAS guidelines must include:

- a description of the technical and availability requirements of SRAS;
- a process for meeting the SRAS aggregate required reliability requirement of the Standard for each electrical sub-network;
- a process for the modelling, assessment and physical testing of SRAS by an SRAS Provider, including any assumptions to be made by AEMO regarding the state of transmission elements during a major supply disruption;
- a process for determining the number and location of SRAS required to be procured for each electrical sub-network consistent with the Standard;
- guidance to Registered Participants on the factors that AEMO must take into account when making a decision to follow a particular type of procurement process to acquire SRAS;
- a process for AEMO to follow for contacting a potential SRAS Provider to negotiate the provision of SRAS without a competitive tender process; and
- a process for a potential SRAS provider to contact AEMO to offer the provision of system restart ancillary services without a competitive tender process, which offer AEMO is in no way obliged to accept.

164 Clause 3.11.7(c) of the Rules

AEMO is responsible for procuring SRAS to meet the Standard at the lowest cost.[165] AEMO assesses the ability of procured SRAS to meet the parameters of the Standard through detailed testing and power system modelling.

AEMO is also required to report annually on the total annual cost of SRAS in each sub-network and region, and whether SRAS was not procured to a level satisfactory to meet the Standard in any sub-network.[166]

AEMO facilitates the recovery of the cost of SRAS from those regions that benefit from the SRAS service.[167] These costs are split equally between Generators and Market Customers.

AEMO must also develop a confidential System Restart Plan for the purpose of managing and coordinating system restoration activities during any major supply disruption. The plan must be consistent with the Standard.[168] In addition, AEMO is required to prepare guidelines for usage by networks and generators to develop their black start procedures.[169] The networks and generators must submit the black start procedures to AEMO for approval (see below).

In addition, AEMO must consult with the relevant network business to identify and resolve issues in relation to the capability of SRAS proposed to be provided by an SRAS Provider.[170]

Networks

The networks are responsible for providing AEMO with information to facilitate the procurement of SRAS.[171] They must provide information that AEMO reasonably requires to assess the capability of a SRAS to meet the Standard.

The networks are also required to prepare and submit to AEMO local black start procedures that would be utilised during a black system event. Amongst other matters, local black system procedures must provide information to enable AEMO to understand the likely condition and capabilities of plant following any major supply disruption so that AEMO can co-ordinate the safe implementation of the system restart plan. This may be amended, if there is a change of circumstances or a request from AEMO.[172]

Generators

Generators with the relevant specialised equipment are able to offer to provide SRAS. Generators that receive payment for the provision of SRAS are required to maintain their restart capacity and undertake regular testing as set out in the guidelines.

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165 Clause 3.11.7(a1) of the Rules.

166 Clause 3.11.10 of the Rules.

167 Clause 3.15.6A(c2) of the Rules.

168 Clause 4.8.12(c) of the Rules.

169 Clause 4.8.12(e) of the Rules.

170 Clause 3.11.7(b) of the Rules.

171 Clause 3.11.9(I) of the Rules.

172 Clause 4.8.12(d) of the Rules.

Generators must prepare and submit to AEMO local black system procedures on the actions that would be taken in the eventuality of a major supply disruption.[173]

Roles and responsibilities during a major supply disruption

This section describes the specific roles and responsibilities of parties during the restoration of the power system following a major supply disruption. These parties include AEMO, TNSPs, Generators and the JSSC.

AEMO

AEMO has overall responsibility for coordinating the restart and restoration process. AEMO will first make an assessment of the extent of the major supply disruption and whether there is a black system condition. In addition to the information available from SCADA,[174] AEMO will request status information availability and damage of the major generating units from the generators and the transmission network from the relevant TNSP.

AEMO will then determine the fastest and most reliable process to restart the part of the network affected by black system condition. This will include consideration of whether the network can be restarted from a neighbouring electrical sub-network or from a generating unit that has remained operating, or whether the restoration process would be faster if one or more of the procured SRAS sources were to be used. If SRAS is required then AEMO will call on these services. This may require the TNSP connecting one or more of its transmission lines.

AEMO, in coordination with the TNSP and DNSPs, will coordinate the rebuilding of the transmission network following its System Restart Plan. AEMO will ensure that no elements are overloaded and that voltage stays within acceptable limits when a network element is reconnected. AEMO also coordinates the switching on of small blocks of load to stabilise the system frequency and the voltage profile of the operating network.

TNSPs

An affected TNSP will need to assess the status of its network following a major supply disruption. In particular, the TNSP will determine to extent of the supply disruption on its network, if any of its network elements are damaged and whether any of the generating units on its network are still operating.

The TNSP will need to make the necessary preparation to re-energise elements of its network, as required. The re-energisation of any network elements will need to be authorised by AEMO to reduce a collapse of the power system being restored. The TNSP will also need to monitor its network to ensure that the voltage profile across its network is kept within appropriate limits.

The TNSP will also need to liaise with any large transmission connected loads and the associated DNSPs to prepare blocks of load to be connected as the network is restarted

173 Clause 4.8.12(d) of the Rules.

174 Each TNSP operates a system control and data acquisition (SCADA) system for controlling and monitoring its network and the equipment connected to its network. AEMO has access to the SCADA information that it requires to operate the power system via communication links to the TNSPs.

and restored. Reconnecting any load would need to be authorised by AEMO to ensure that the system frequency and the voltage profile remains within appropriate limits.

DNSPs

An affected DNSP will need to assess the status of its network following a major supply disruption. In particular, the DNSP will determine to extent of the supply disruption on its network, if any of its network elements are damaged and whether any of the generating units on its network are still operating.

The DNSP will need to make the necessary preparation to restore supply to small blocks of load, as required. The re-energisation of any load will need to be coordinated with the TNSP and be authorised by AEMO to reduce a collapse of the power system being restored. The DNSP will also need to monitor its network to ensure that the voltage profile across its network is kept within appropriate limits, particularly in the sub-transmission parts of its network.

Generators

An affected generator will need to assess the status of its generating units after a major supply disruption. In particular, the DNSP will generator will need to determine which of its generating units are still operating and assess if any of its units are damaged. The generator will need to stabilise the operation of any of its generating units, to the extent possible.

The generator will also need to prepare its units for restarting, particularly those that have been procured under a SRAS contract. The generator will then need to be ready to respond to AEMO instructions and directions in relation to its generating units.

Jurisdictional System Security Coordinator

AEMO, the TNSP and the DNSPs must coordinate the restoration process with the JSSC.

F Past Reviews and Rule Changes

System restart ancillary service arrangements rule change - 2006

In 2006 the AEMC made a rule concerning the standards, procurement and use of SRAS. Relevant aspects of the 2006 rule change included changes to the SRAS Objective and a clarification of the contents of the contents of the Standard.[175] As required by this rule, AEMO (then NEMMCO) created an Interim Standard in 2006 following public consultation, and the approval of the Panel.

Review of the System Restart Standard – 2012

The Panel was required under the Rules to undertake a review of the Interim Standard. This review was completed in 2012 and largely retained most of the Interim Standard that had been previously developed by AEMO. The Panel made only minor changes to the System Restart Standard at this time, which was intended to improve clarity.

Review of SRAS Guidelines – 2013

In 2014 AEMO reviewed the SRAS Guidelines.[176] In its final determination, AEMO reconsidered its initial approach and made the following changes to its SRAS Guidelines by:

- clarifying that when AEMO procures SRAS it would assume supply would not be available from adjoining electrical sub-networks;
- removing the requirement to procure a minimum of two SRAS sources for each electrical sub-network area, with AEMO procuring the optimal quantity of SRAS to efficiently meet the System Restart Standard in each electrical sub-network;
- recognition that individual, lower reliability SRAS may be combined to meet the System Restart Standard;
- assuming that the transmission network would be fully available, subject to standard technical limitations, following a major supply disruption; and
- clarifying the boundary between the Queensland South and New South Wales electrical sub-networks.

175 AEMC, System restart ancillary service arrangements and pricing under market suspension, Final Determination, April 2006.

176 AEMO, System Restart Ancillary Services - Draft Report, May 2013.