RELIABILITY PANEL AEMC

PANEL DETERMINATION

Reliability Panel AEMC

FINAL DETERMINATION

Review of the System Restart Standard

15 December 2016

Reference: REL0057: Determination

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Reference: REL0057

Citation

Reliability Panel, Review of the System Restart Standard, final determination, 15 December 2016, Sydney

About the Reliability Panel

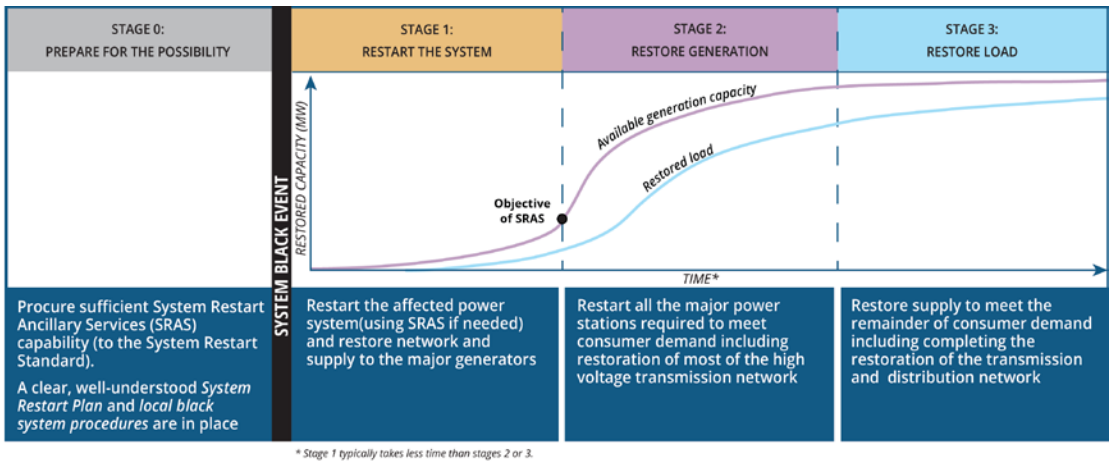
The Reliability Panel (Panel) is a specialist body established by the Australian Energy Market Commission (AEMC) and comprises industry and consumer representatives. It is responsible for monitoring, reviewing and reporting on reliability, security and safety of the national electricity system and advising the AEMC in respect of such matters. The Panel's responsibilities are specified in section 38 of the National Electricity Law. This work is copyright.

Executive Summary

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 the Australian Energy Market Operator (AEMO) for managing the power system within a secure operating state. While unplanned events can and do occur in the power system, these frameworks contain mechanisms to stabilise the system following such events and maintain continued supply to consumers.

The mechanisms established by the Rules are used to maintain the power system in a secure state 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 mechanisms. These rare events can potentially result in a major supply disruption, or black system event, that shuts down entire sections of the power system and causes generators to disconnect from or 'trip off' the network, with significant economic and social cost impacts for a large number of consumers.

To minimise 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. The process for restoration has several stages and involves AEMO, transmission and distribution network service providers and generators. An overview of the stages involved in preparing for and responding to a black system event is illustrated below:



Under the Rules, AEMO has overall authority for restoration of the power system (stages 1-3) and generators, network service providers and jurisdictional system security coordinators (JSSCs) are obliged to provide relevant information and assist with the restoration process. AEMO's system restart plan contains all relevant procedures that are followed in that process.

In preparing for a black system event, AEMO procures System Restart Ancillary Services (SRAS). SRAS is a service that can only be offered by some generators who have restart capability and acts a failsafe or 'back up' service. It provides a dependable 'restart' capability when other generators cannot restart after a black system event. In the event of a major supply disruption in a region, supply may be provided from an interconnected region or SRAS within the disrupted region may be used to supply

sufficient energy to restart power stations in order to begin the process of restoring the power system.

The Reliability Panel (Panel) is responsible for determining, modifying and publishing the System Restart Standard (the Standard) which guides AEMO's procurement of SRAS by defining a timeframe within which SRAS should restore a specified level of generation capacity.

The Panel has determined a revised Standard in accordance with terms of reference issued to it by the Australian Energy Market Commission (AEMC). Its review of the Standard is outlined in this final determination.[1]

What is the Standard?

The Standard specifies the time, level and reliability of generation and transmission capacity to be available for the restoration process following a major supply disruption (or black system event) that results in an uncontrolled power outage in one or more electrical sub-networks[2] in the NEM. As such the Standard provides a target for the procurement of SRAS by AEMO. It is a standard for procurement rather than an operational standard. Operationally, AEMO works in conjunction with generators, network service providers and JSSCs to restore the power system and customer load as quickly as possible.

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 to restart auxiliaries such as pumps, fans and fuel systems. Not all generators have this restart capability given the additional cost this capability creates for a generator. AEMO must, in accordance with the Rules, ensure there are sufficient restart services available, which it does by procuring SRAS in accordance with the Standard.

The Panel is required to determine the Standard in accordance with the SRAS Objective.[3] The objective for SRAS is to minimise the expected costs of a major supply disruption to the extent appropriate having regard to the National Electricity Objective (NEO). Consideration of the NEO meant the Panel considered various economic factors, including the trade-offs that exist between the cost of procuring restart services against the short term costs of a loss of supply and the longer term costs of economic disruption. AEMO then procures SRAS at the lowest cost to a level that is in accordance with the Standard.

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1 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 SRAS: AEMC 2015, System Restart Ancillary Services, Rule Determination, 2 April 2015, Sydney

2 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.

3 "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."

What the Standard does not specify

The goal of the Standard is to ensure that sufficient generation and transmission network capability is restored so that 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 beyond the scope of the Standard. Nor does the Panel consider it appropriate to define the Standard, and hence the appropriate level of SRAS procurement, to include load restoration. This is because it is network service providers who are responsible for reconnecting consumers and reconnection can be dependent on a great variety of issues (such as network damage) that are beyond the scope of the Standard.[4] It would be difficult and unhelpful for AEMO to be required to estimate the time to do this and provide for it when it is procuring required SRAS.

The Standard does not otherwise address the technical requirement of or testing of SRAS. These operational matters are addressed in the Systems Restart Ancillary Services Guidelines prepared by AEMO in accordance with the National Electricity Rules (Rules).

The Final Standard

Set-points for time, level and aggregate reliability

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 each affected sub-network could be supplied within four hours of a major supply disruption occurring.

The Final Standard the Panel has determined provides a more stringent target for procurement than that under the current Standard. The Final Standard has been tightened in a number of key ways:

- **Tailoring to sub-networks**. Under the Final Standard the time in which, level and aggregate reliability of, generation and transmission capacity required to be available for the restoration process differs between electrical sub-networks. The Panel has 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 unique to the sub-network; and the economic circumstances that apply to each individual sub-network.
- **Minimising SRAS costs.** The minimum level of generation and transmission capacity to be restored by SRAS in each sub-network is lower in this Determination than the level set out in the current Standard, of 40 per cent of peak demand in the sub-network. The level in the current Standard is set at a level that is higher than the normal demand requirement consumers have in most electrical

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

sub-networks and is well beyond the level required to restart the system. Leaving the level of generation and transmission capacity at an unnecessarily high level does not minimise the costs of either the SRAS to be procured or the costs to consumers of a black system event.

- **Using better metrics – level of generation**: The Panel has determined that the level of generation will be expressed in a MW quantity, instead of the current Standard in which the level of generation is expressed as a percentage of peak demand. The quantity of generation is a more appropriate way to express this aspect of the Standard. The level of supply required to restart an electrical sub-network depends more on the quantity, type and technical capability of generation, and on the characteristics of the transmission network. The level of supply required for a restart is unlikely to change significantly as demand within the electrical sub-network varies over time.
- **Restoring capacity faster.** The time in which the generation and transmission capacity must be restored in each sub- network is shorter in this Determination than the current Standard. This will allow the subsequent stages of the restoration process to commence faster.
- **Including aggregate reliability.** The Standard now includes an aggregate reliability level for the restoration of the generation and transmission capacity in each of the electrical sub-networks. Aggregate reliability refers to the overall reliability of SRAS (and the reliability of relevant transmission components) procured for a sub-network rather than the reliability of each individual SRAS source procured for the sub-network. The aggregate reliability level in the Standard targets an efficient level of SRAS procurement and 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 also expand the depth of the SRAS market and so 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 set points for restoring the generation and transmission capacity in each electrical sub-network determined by the Panel.

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

Electrical Sub-Network	Level of Restoration	Restoration time	Aggregate Reliability
North Queensland	825 MW	3.5 hours	90%
South Queensland	825 MW	3.0 hours	90%
New South Wales	1500 MW	2.0 hours	90%
Victoria	1100 MW	3.0 hours	90%
South Australia	330 MW	2.5 hours	90%
Tasmania	300 MW	2.5 hours	95%

Additional requirement on SRAS procurement in New South Wales

The Final Standard now also includes a requirement to:

> "independently restart, without drawing power from the power system, at least 500 MW of generation capacity north of Sydney within four hours of a major supply disruption with an aggregate reliability of at least 75 per cent."

This requirement is included in the Final Standard to provide additional and specific guidance to AEMO when procuring SRAS in New South Wales. This is because 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.

Guidelines to require AEMO to consider diversity when assessing reliability in each sub-network

The Rules require the Standard to include guidelines for AEMO to consider diversity and the strategic locations of restart services. Diversity is a reference to the electrical, geographical and energy source diversity between the sources of SRAS within an electrical sub-network. These guidelines are amended in the Final Standard which now specifically requires AEMO to consider diversity when it assesses the aggregate reliability of each sub-network. This clarifies how the diversity guidelines within the Standard are intended to operate in relation to aggregate reliability and will result in AEMO having clearer guidance as to how it should treat diversity between the restart services.

The Final Standard also makes clear that the treatment of electrical diversity of SRAS within a sub-network needs to consider the failure of any single significant transmission element, such as a single line or corridor, that is downstream of the first transmission substation in the restoration path. This will mean that AEMO will need to consider the potential for some network damage, occurring as part of a major supply disruption, when assessing electrical diversity of SRAS between potential restart services.

Guidelines for the determination of electrical sub-networks

The Standard also includes guidelines for AEMO when it defines the boundaries of the electrical sub-networks. They require AEMO to take certain technical characteristics into account when considering these boundaries. The Standard amends these

guidelines to provide AEMO with clearer guidance for any such boundary definition. The guidelines now require AEMO to consider relevant technical characteristics of the power system that best facilitate the achievement of AEMO's power system security responsibility of procuring adequate system restart ancillary services that enable it to co-ordinate a response to a major supply disruption.

Advice provided to the Panel

In determining the Standard in accordance with the SRAS Objective, the Panel was informed by:

- Technical advice from AEMO, which included advice on 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 Standard that is equivalent to, or better than in some respects, the world's best practice requirements for system restoration.
- An initial consideration of the black system event that occurred on 28 September 2016, in South Australia, based on AEMO incident reporting as at 7 December 2016.

The Standard has also been determined on the assumption that AEMO cannot rely on supply from a neighbouring sub-network when restoring supply to the generation and transmission system in a sub-network. The Standard, therefore, identifies the maximum amount of time within which SRAS is required to return supply in an electrical sub-network under this assumption. The requirement to make 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 Standard on such an assumption, the procured SRAS is distributed throughout the NEM and will also provide greater assurance against the very unlikely occurrence of a major supply disruption affecting the whole NEM.

Recommendations for change

Throughout the Panel's review of the Standard, the Panel has become aware of a number of concerns stakeholders have in relation to the restoration process that are outside the scope of the Standard, and the Panel's remit to address through this review. However, in this determination the Panel has expressed a view of these issues to assist further discussion and made recommendations where appropriate. The Panel will monitor the implementation of these recommendations to consider their impact on system security more generally

In summary the Panel's recommendations on these matters are as follows.

- JSSCs' roles in each jurisdiction should, to the extent it doesn't already, extend to communication in relation to expected timeframes for the restoration of load that takes place in Stage 3 of the restoration process.

- During the review process the Panel became aware that the detailed and involved nature of the system restoration process, and the various roles of the parties involved at each of the three stages, was not generally well understood by many stakeholders. Given the potential significance of a major supply disruption, as evidenced by the black system event in South Australia, it is important that everyone who has a role understands what can be involved in restoring a system, specifically the unpredictability of the timeframe that can occur between restoring generation and returning supply to consumers within a large distribution network such as a large CBD.

- AEMO, the relevant TNSP and DNSPs, as well as the JSSC for each electrical sub-network develop plans for the complete restoration process from a black system condition being declared to the restoration of all consumers' load.
  - While the Standard is only concerned with the restarting of an electrical sub-network following a major supply disruption, it is also important that the entire process for restoring generation and consumer load is effective.
  - The existing system restart plans cover the first two stages of the restoration process following a black system condition, that is, the re-energising of the transmission network and restoration of supply from major power stations. However, these plans do not cover the full process of returning restoring supply to all consumer loads. Similarly, the network service providers have plans for the restoration of load following a supply disruption. The Panel is not aware of any comprehensive restoration plans that cover the whole of the load restoration from a black system condition.
  - The Panel expects that the development of these plans would provide valuable information for the development of state emergency management plans.
- AEMO explore avenues through which it might be able to increase engagement with key stakeholders, such as network service providers, in relation to its consideration of key elements relevant to its procurement of SRAS.
  - The Panel is aware that some stakeholders consider that the current SRAS procured by AEMO may not comply with the current Standard. While AEMO is not obliged to consult with relevant stakeholders in relation to the level of SRAS it is procuring, the Panel considers that there is value in AEMO engaging with network service providers in relation to its assumption on restoration of generation and the transmission networks.
- Testing of SRAS capability is an integral part of the restoration process and is subject to both SRAS Guidelines and other contractual obligations between AEMO and SRAS Providers. Full testing of a restart service can be difficult as it can involve taking transmission elements out of service. However, the Panel recommends that SRAS providers and transmission network service providers cooperate more fully to identify opportunities to fully test the operation of restart services when this involves normally 'in service' transmission elements and/or the subsequent generation units in the restoration path. For example, it

may be possible to perform a more comprehensive test of a restart service when the associated transmission elements and/or generation are being returned to service following a planned outage.

When does the Final Standard commence

The Final Standard commences 1 July 2018.

SRAS that has been procured in accordance with the current Standard has been procured for the period from 1 July 2015 to 30 June 2018. The Final Standard will apply to AEMO's next procurement process of SRAS that will need to be procured by 1 July 2018.

Differences between the Draft and Final Standard

The Panel made the following changes from the Draft Standard in determining the Final Standard:

- The level of generation and transmission capacity required to be restored is now expressed in MW rather than as a percentage of the average demand in the electrical sub-network.
- The time is which generation and transmission capacity is required to be restored is reduced to more closely match the generation restoration curves provided in AEMO's advice to the Panel.
- The aggregate reliability requirement for the Tasmanian sub-network has increased to 95 per cent because, unlike the other sub-networks, Tasmania cannot rely on restoration from an interconnector following a major supply disruption in the event that the procured SRAS does not operate successfully.[5] The Basslink interconnector cannot be used as a restart source for Tasmania because it can only operate when the Tasmanian (and Victorian) sub-networks are already operating.
- The assessment of the reliability of sources of SRAS AEMO procures needs to include the reliability of the transmission components between the restart service and the first transmission sub-station to which it is connected. This has been included to account for the risk that network damage or unavailability could prevent to the operation of a source of SRAS.
- The treatment of electrical diversity of SRAS within a sub-network needs to consider the failure of any single significant transmission element, such as a single line or corridor, that is downstream of the first transmission substation in the restoration path. This has been included to account for the risk of transmission network damage when assessing electrical diversity of SRAS between potential sources of SRAS.
- In determining the boundaries of electrical sub-networks , the Standard now requires AEMO to give consideration to the technical characteristics of the power system as part of its broader power system security responsibility.

5 While AEMO is required to procure SRAS to meet the Standard without relying on a neighbouring sub-network, the Panel has considered that all the sub-networks except Tasmania have the potential to be restarted using an interconnector in the event that the procured SRAS does not operate.

Reliability Panel members

Neville Henderson, Chairman and AEMC Commissioner

Trevor Armstrong, Chief Operating Officer, Ausgrid

Lance Balcombe, Chief Executive Officer, TasNetworks

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

Mark Collette, Energy Executive, Energy Australia

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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

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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).[6] The Panel's findings are set out in this report.

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.[7] 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 restart capability.[8] SRAS are special generation services that AEMO may call upon to assist in the restoration of supply[9] 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.[10] 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.[11]

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 beyond the scope of the Standard, and is not considered in this review.[12]

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

7 Clause 8.8.3(aa) of the Rules.

8 Clause 3.11.7(a1) of the Rules.

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

10 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.

11 Clause 4.8.12(c) of the Rules.

12 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[13] and guidance on the boundaries of electrical sub-networks.

1.2 Requirements of the Review

On 30 June 2015, the 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.[14]

The Terms of Reference required 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.[15]

The Panel's review did not consider processes for reconnecting consumers' load following a normal supply disruption as there are existing arrangements for reconnecting load. In addition, the review did 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 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 revise the SRAS Guidelines so that they are consistent with the final Standard before AEMO begins the procurement process for SRAS that must be in place by 1 July 2018. SRARS currently procured in accordance with the current standard is in place from 1 July 2015 until 30 June 2018.

1.3 Timetable for the Review

In carrying out this Review, the Panel followed 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),[16] including in some cases representatives from the regional

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

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

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

Transmission Network Service Provider and other State Government representatives, to 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 published a draft determination and Draft Standard on 25 August 2016. The Panel held a second public forum on 21 September 2016 to present the Draft Standard and to seek stakeholder views on the Panel's draft determination. Submissions on the draft determination and Draft Standard were due on 6 October 2016 but this timeframe was extended by the Panel to 27 October 2016 to allow stakeholders time to consider additional information regarding AEMO's advice to Panel for the draft determination. The Panel published this additional information on 17 October 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	27 October 2016
Final determination and Final Standard	15 December 2016

1.4 Specialist Advice

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

16 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.

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.
- The Panel requested Mr Mal Park to provide it with a peer review of the generation restoration advice for New South Wales.[17] This gave the Panel confidence following some stakeholders' concerns with the advice provided by AEMO.

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 Structure of the determination

The remainder of this 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, including the Panel's consideration of the National Electricity Objective and the SRAS Objective;
- Chapter 4 sets out a summary of specialist advice that the Panel received to inform its determination of the Standard, including a report on the international

17 Mal Park was the original author of the NSW "Black Start" operating manual OM666, while working as the Assistant Operations Planning Engineer with The Electricity Commission of NSW. Later reviewing and updating OM666 many times including the formation of operator training procedures and processes. In later years Mal was the NSW representative on the NEMMCO "Interregional Planning Committee" (IRPC) as the Executive Manager/Strategic Network Development with TransGrid.

experience of major blackouts and restoration and advice provided by AEMO on the technical characteristics of the power system.

- Chapter 5 summarises the results of the economic assessment of SRAS and subsequent additional sensitivity analysis undertaken by Deloitte Access Economics on behalf of the Reliability Panel;
- Chapter 6 discusses Panel's rationale for the determination of the final standard based on the advice described in chapters 4 and 5; 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. Unplanned events causing disruptions to the system may occur periodically. However the Rules framework includes mechanisms to stabilise the system following these events, so power supply to consumers either remains unaffected or is lost and quickly restored.

In fact AEMO is required to maintain the transmission network in a secure operating state so that consumer supply remains uninterrupted even if a single 'contingency event the occurrence of which AEMO considers to be reasonably possible' transpires.[18] Such an event is termed a 'credible contingency' and includes when a single transmission line or transformer fails or is unexpectedly removed from operation, or a single generating unit disconnects (or 'trips') from the network.

As we saw in South Australia in September 2016 certain unpredictable and severe events such as storms (or bushfires) can disturb the power system more significantly than these smaller network disruptions which the power system is designed to manage.[19] In rare cases multiple parts of a network may be disrupted. If the power supply to a large part of a transmission system is unexpectedly lost, one or more generators in that part of the network may trip off the system and cease supplying power into the network. They may be unable to start generating power again as they cannot source power from the transmission network. Where a major supply disruption of this type involves a significant part of a transmission system or region and affects a significant number of consumers it is termed a 'black system condition'.[20] In a black system condition it is critical that a power source independent of the transmission system is available to restart the generators, so as to re-energise the transmission and distribution networks and return power to consumers.

Various reviews are examining the causes of and responses to the South Australian black system condition. This Review of the System Restart Standard specifically focuses on having sufficient stand-alone generators available to AEMO so that that the electricity system can be restarted in the event that a large number of generators trip off

18 Clause 4.2.3(b) of the Rules.

19 Small supply interruptions in the distribution networks are more common than larger transmission interruptions. 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. Also transmission assets are normally less susceptible to disruption.

20 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." 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).

the system and cannot source power to restart from the transmission network. Where events in South Australia are pertinent to the scope of this Review the Panel has considered and incorporated lessons learnt into its analysis and deliberations.

2.1 The System Restart Standard

2.1.1 What is the System Restart Standard?

Put simply, the System Restart Standard (the Standard) sets the level of restart capability that AEMO must procure so power generation and transmission can be restarted – independent of the rest of the transmission network – following a black system condition.

The Standard specifies the restart capability to be procured in each electrical sub-network. It specifies:

- the level of generation and transmission capacity to be available for the restoration process following an uncontrolled full or partial power outage in one or more electrical sub-networks in the NEM (referred to a major supply disruption or black system event);
- the maximum time allowable to restore this level of capacity in the sub-network;
- the aggregate reliability of the generation and transmission in a sub-network to be restored to the specified level within the specified time.

As such the Standard provides a target for the procurement of SRAS by AEMO, it is, a procurement standard rather than an operational standard. While AEMO would aim to restore the power system to the requirements of the Standard or better 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. The Standard is a procurement standard rather than an operational standard.[21] Clause 3.11.7 of the Rules 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)".

2.1.2 What are System Restart Ancillary Services (SRAS)?

SRAS is a system restart service provided by a generator capable of independently restarting 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 involved (see section 2.1.3). SRAS acts a failsafe or 'back up' service that is intended to provide a dependable 'restart' capability. It is only expected to be required infrequently.

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

The Standard provides a target for the procurement of SRAS by AEMO. AEMO must procure sufficient SRAS to meet the requirements of the Standard.

During normal NEM operation AEMO is responsible for procuring SRAS to the levels prescribed by the Standard from generators that have the ability to restart independently of the NEM and have sufficient capacity to restart other nearby generating units, once they are connected. This is called 'black start capability'.[22] 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 without 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.[23]

Contracted generators must maintain the capability of the contracted SRAS sources, for instance through regular testing and staff training.

2.1.3 When might System Restart Ancillary Services be utilised?

SRAS (procured to meet the Standard) may be utilised in some black system conditions. If there is zero voltage in the transmission network power to restart tripped generators can be drawn from:

- an unaffected part of the transmission network; or
- an isolated pocket of generation and load that remained operating within the affected region.

Where supply is not readily available from unaffected parts of the network or within an affected region, power to restart the affected system needs to be provided from SRAS.

2.1.4 When have System Restart Ancillary Services been used?

Since the commencement of the NEM, there have been two black system conditions declared.

---

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

23 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.

South Australia (2016)

At 16.18 on Wednesday 28 September 2016 there was a black system event in South Australia. This event was associated with severe weather including high winds, thunderstorms, lightning strikes, hail, and heavy rainfall. The weather resulted in multiple transmission system faults and there was also a loss of generation within South Australia that lead to the Heywood interconnector tripping. This resulted in the remaining generation and load in South Australia being lost.

Information on the black system event and the associated restoration is available in AEMO's preliminary report published on 5 October 2016 and its update report published on 19 October 2016.[24] These reports have been prepared as part of AEMO's statutory role to investigate incidents such as black system events.[25]

Following the black system event, AEMO performed an initial assessment of the system conditions and commenced a process to restore supply to South Australian customers. The two restart services contracted to provide SRAS in South Australia experienced difficulties and did not perform as expected. AEMO is continuing to investigate why this happened. At 17:23, the Heywood interconnector was progressively energised through to Adelaide to restart Torrens Island Power Station and provide a basis to allow customer supply to be restored.

The main issues that arose from the events associated with the black system event are:

- the two contracted restart services did not operate as expected, which lead to an initial delay to the restoration;
- the operation of one contracted restart service was unsuccessful due to the malfunction of a critical circuit breaker, required to energise a large generating unit;
- the operation of a second contracted restart services was affected by damage to associated generation and network infrastructure;
- the interconnector to Victoria was used to successfully restart South Australian generation; and
- a portion of the South Australian demand was interrupted for a prolonged period due to damaged network elements.

AEMO is expected to report further on the event.

Northern Queensland (2009)

A previous event occurred in northern Queensland in 2009. This event was caused by a non-credible contingency event.[26] In this case supply to the affected area was restored

24 The AEMO reports on the South Australian black system event and restoration are available on the AEMO website www.aemo.com.au

25 Clause 4.8.15 of the Rules.

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

by progressively reconnecting the transmission network from the operating power system in central Queensland.

Lessons from previous black system events

As occurred in the South Australia and Queensland events 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 without using restart services. However, it is also possible that supply may not be readily available from a neighbouring part of the network. In this case, power from SRAS provides an independent ability to re-energise the affected power system.

2.1.5 The role of the System Restart Standard in the restoration process

While the Standard and SRAS contribute to the overall restoration of supply to consumers they are only critical to first of the three stages in the system restoration process as defined below:

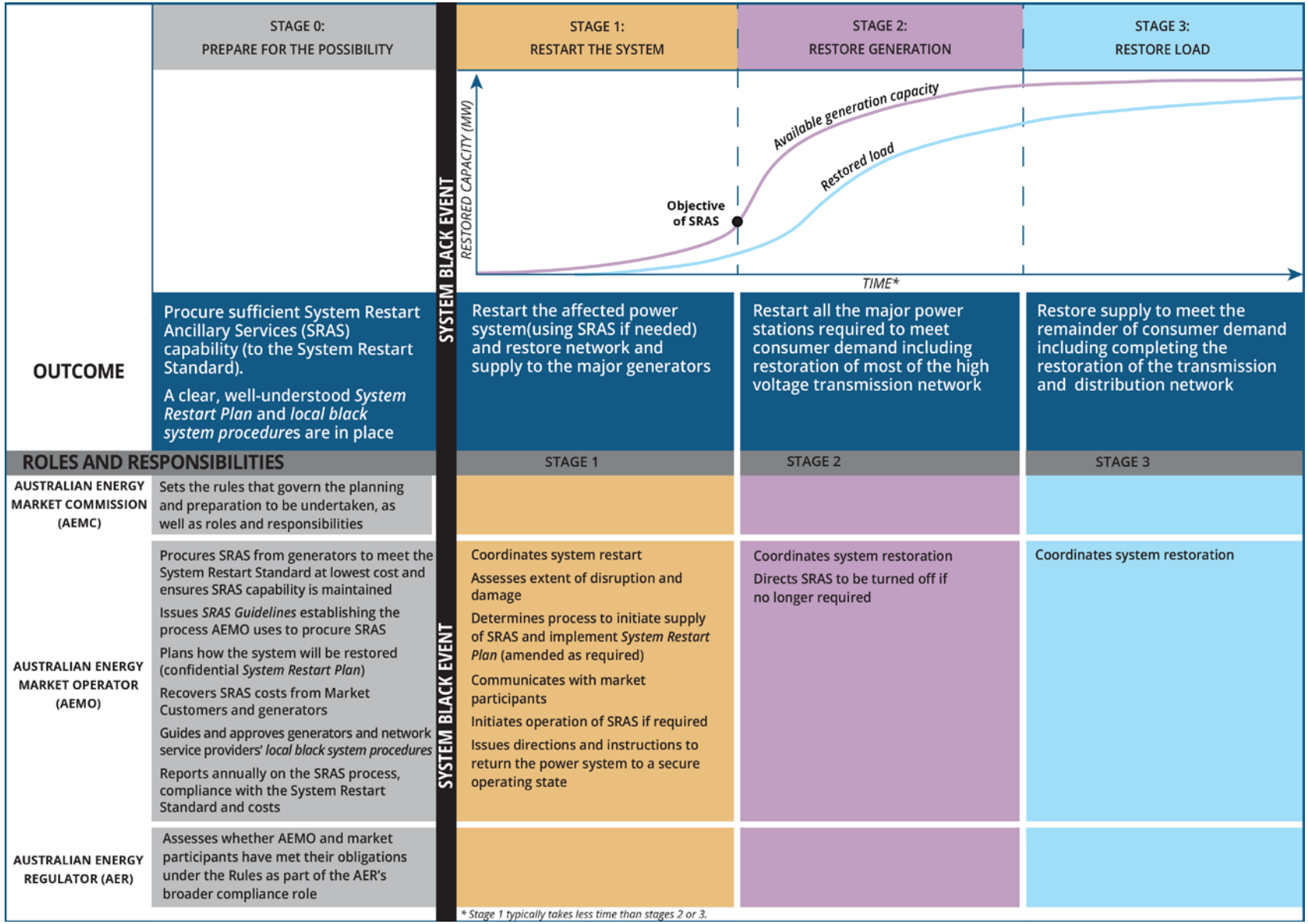
- **Stage 1**: Restart the system, by SRAS if required
- **Stage 2**: Restore generation
- **Stage 3**: Restore load to customers.

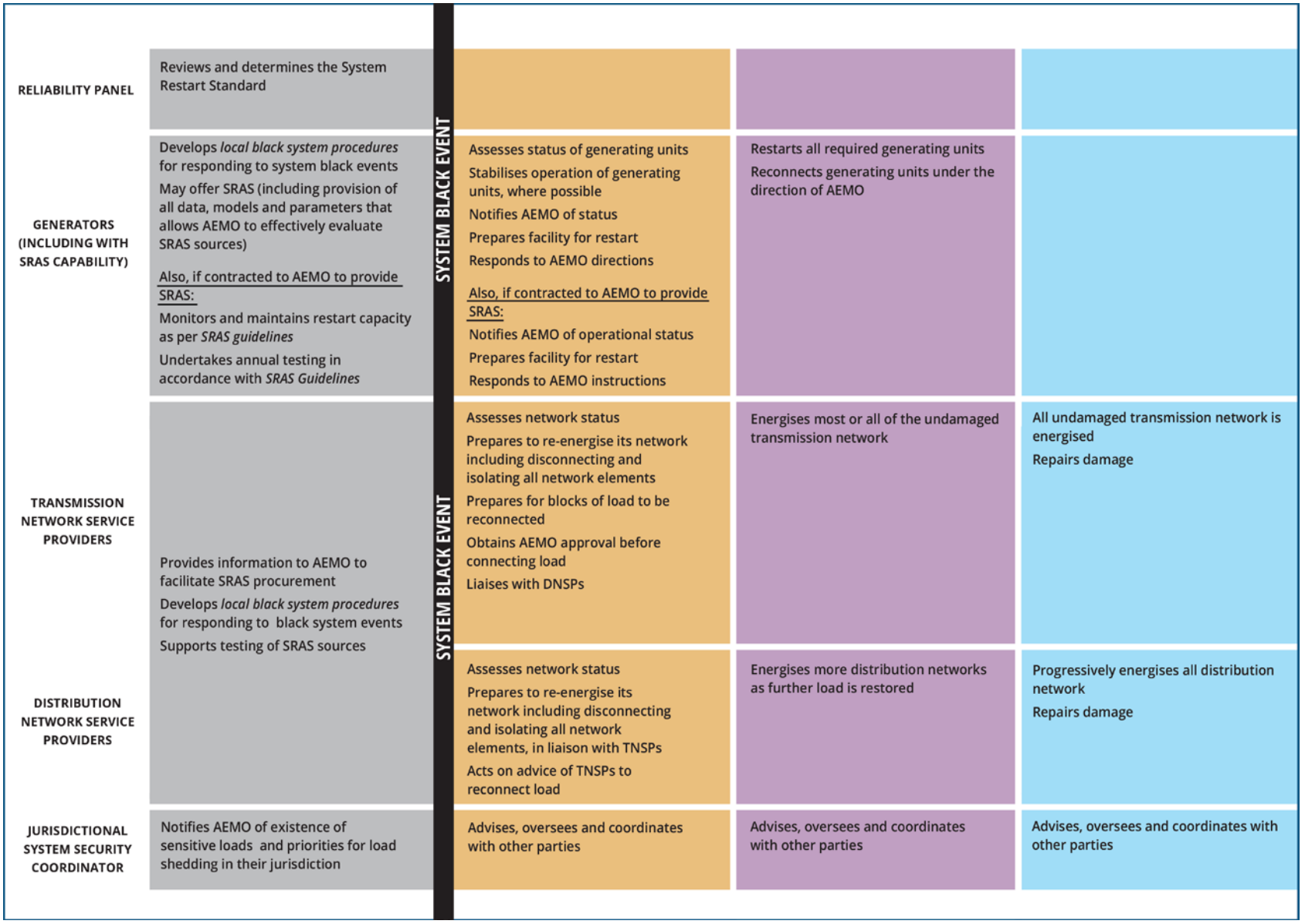
The respective roles and responsibilities of market institutions and market participants for Stage One through to Stage Three of the system restoration process are summarised in Figure 2.1, with more details provided in Appendix E.

In Stage One, SRAS facilitates the restoration process by supplying auxiliary power loads to the major power stations to enable them to restart independently of the transmission system.[27] While the Standard sets the overall procurement target for SRAS it does not address matters of SRAS implementation during Stage One. Issues such as the SRAS procurement approach, and the maintenance and testing obligations on SRAS generators, are specified in SRAS Guidelines developed by AEMO.

27 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.

Figure 2.1: Black system conditions: preparation and response




SYSTEM BLACK EVENT
SYSTEM BLACK EVENT
RELIABILITY PANEL
Reviews and determines the System Restart Standard
GENERATORS (INCLUDING WITH SRAS CAPABILITY)
Develops local black system procedures for responding to system black events
May offer SRAS (including provision of all data, models and parameters that allows AEMO to effectively evaluate SRAS sources)
Also, if contracted to AEMO to provide SRAS:
Monitors and maintains restart capacity as per SRAS guidelines
Undertakes annual testing in accordance with SRAS Guidelines
Assesses status of generating units
Stabilises operation of generating units, where possible
Notifies AEMO of status
Prepares facility for restart
Responds to AEMO directions
Also, if contracted to AEMO to provide SRAS:
Notifies AEMO of operational status
Prepares facility for restart
Responds to AEMO instructions
Restarts all required generating units
Reconnects generating units under the direction of AEMO
TRANSMISSION NETWORK SERVICE PROVIDERS
Provides information to AEMO to facilitate SRAS procurement
Develops local black system procedures for responding to black system events
Supports testing of SRAS sources
Assesses network status
Prepares to re-energise its network including disconnecting and isolating all network elements
Prepares for blocks of load to be reconnected
Obtains AEMO approval before connecting load
Liaises with DNSPs
Energises most or all of the undamaged transmission network
All undamaged transmission network is energised
Repairs damage
DISTRIBUTION NETWORK SERVICE PROVIDERS
Assesses network status
Prepares to re-energise its network including disconnecting and isolating all network elements, in liaison with TNSPs
Acts on advice of TNSPs to reconnect load
Energises more distribution networks as further load is restored
Progressively energises all distribution network
Repairs damage
JURISDICTIONAL SYSTEM SECURITY COORDINATOR
Notifies AEMO of existence of sensitive loads and priorities for load shedding in their jurisdiction
Advises, oversees and coordinates with other parties
Advises, oversees and coordinates with other parties
Advises, oversees and coordinates with other parties

Once key generators have been restarted the remaining power stations can also restart (Stage Two) and subsequently consumer load can be fully restored (Stage Three). The Standard does not play a role in Stages Two or Three of the system restoration process.

The purpose 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.

2.1.6 What the System Restart Standard does not specify

The Standard does not specify the time period within – nor the level to which – load must restored to consumers. There are several reasons for this. Firstly the nature and duration of the restoration process depends on the characteristics of the specific circumstances that have occurred, including the extent of equipment damage. The features of the affected power system are also material; for instance the generation types, physical distances between generating units and load centres, and degree of regional interconnection. Such factors affect the time taken to restore power to consumers and cannot be directly affected by the procurement of SRAS (an exception is the distribution of SRAS across the NEM, discussed in section 2.3.1).

Secondly the ability to restore power to consumers rests with the operators of the transmission and distribution networks. SRAS and hence the Standard cannot influence the behaviour of network service provider operations personnel. Consumer load is restored in accordance with AEMO's system restart plan and local black system procedures developed by network service providers and approved by AEMO, as shown in Figure 2.1 and detailed in Appendix E.

2.2 Why is the System Restart Standard important?

Major supply disruptions are rare by international standards. But when they do occur they can result in serious consequences and threats to life and the economy of the affected jurisdiction. 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 11 deaths occurred during the disruption.[28]

The Rules require the Panel to determine the Standard through a review process and the Standard becomes a procurement target for AEMO when it procures restart services.

[28] International experience of major supply disruptions is discussed further in chapter 4, while the economic and societal costs of a major supply disruption are discussed in more detail in chapter 5.

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.[29] 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.

The Standard seeks to balance the costs of additional SRAS and the expected benefits (and avoided costs) that the additional SRAS provides to consumers through a more effective restoration process.

2.3 How is the System Restart Standard set?

2.3.1 Distribution across the NEM

It is important that the procured SRAS are reasonably evenly distributed throughout the NEM. This ensures 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.

To achieve SRAS distribution across the NEM the power system is sub-divided into electrical sub-networks both for acquiring SRAS and developing operational plans to manage major supply disruptions. AEMO is responsible for determining the boundaries of the electrical sub-networks,[30] using criteria specified in the Standard by the Panel.[31]

Currently AEMO has determined that there are six electrical sub-networks.[32] 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.[33]

The Standard provides guidelines to AEMO on how it is to determine the boundaries for the electrical sub-networks.[34] 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

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

30 Clause 3.11.8 of the Rules.

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

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

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

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

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

2.3.2 Related NEM mechanisms to manage a secure system

As described earlier to reduce the likelihood of a major interruption to consumers' power supply AEMO must maintain the NEM transmission network in a secure operating state. If a credible contingency occurs, an event the occurrence of which AEMO considers to be reasonably possible,[35] then AEMO is required to return the system to a secure state within 30 minutes and consumers' power supply should be maintained.

As AEMO is only required to manage system security for single credible contingency events there is a risk that consumers' power supply may be interrupted if a severe *non-credible* contingency event occurs, or if *multiple* credible contingency events arise. For instance the loss of multiple transmission lines during bush fires or the simultaneous tripping of multiple generating units.

The NEM provides mechanisms to reduce the likelihood of multiple credible contingency events occurring and to avoid major supply disruptions. These include:

- 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 (to mitigate the risk of a cascading collapse of the system frequency); and
- network protection systems (to isolate regions that are experiencing a severe major supply disruption from the remainder of the NEM to protect other regions).

2.3.3 Past reviews of the System Restart Standard and related processes

There have been two preceding reviews of the Standard and two Rule changes in relation to the Standard, which are summarised in Appendix E. The 2015 Rule change is most pertinent to the matters considered in this Determination when aspects of the regulatory framework regarding roles, objectives and SRAS procurement were modified.[36]

The following changes were made to clarify the roles and objectives of both AEMO and the Reliability Panel:

- AEMO's objective is to procure sufficient SRAS to meet the Standard at the lowest cost. AEMO is no longer required to meet the broader SRAS Objective. This

35 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.

36 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. The Final Determination is provided at http://www.aemc.gov.au/Rule-Changes/System-Restart-Ancillary-Services

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 Standard through a cost benefit analysis. While the Panel retains 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.[37]

The following changes were made to the Standard's requirements:

- The Standard is to 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 independent of neighbouring sub-networks.
- The Standard is to include an aggregate required reliability for SRAS in each sub-network. This allows AEMO to procure multiple SRAS with varying reliability levels to meet a single aggregate reliability requirement in each electrical sub-network.
- The Standard is to specify that SRAS can only be acquired by AEMO for one electrical sub-network at any one time.
- The definitions of primary and secondary restart services were removed from the Rules as was the Panel's requirement to specify their guidelines.

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

3 Assessment Framework

This chapter sets out the assessment framework that the Panel 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:[38]

> "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 plus the cumulative costs to society of a prolonged disruption to the supply.

When considering the SRAS Objective, the Panel is required to have regard to the National Electricity Objective (NEO), which is:[39]

> "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 in 2015 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.[40] Section 2.3.3 discusses past reviews of the Standard and related processes, including an overview of the Commission's final rule determination on System Restart Ancillary Services published on 2 April 2016.

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 Standard, the Panel has undertaken an assessment of the economically optimal level of SRAS taking into account the technical attributes of the power system. The economically optimal level of SRAS is where the probability

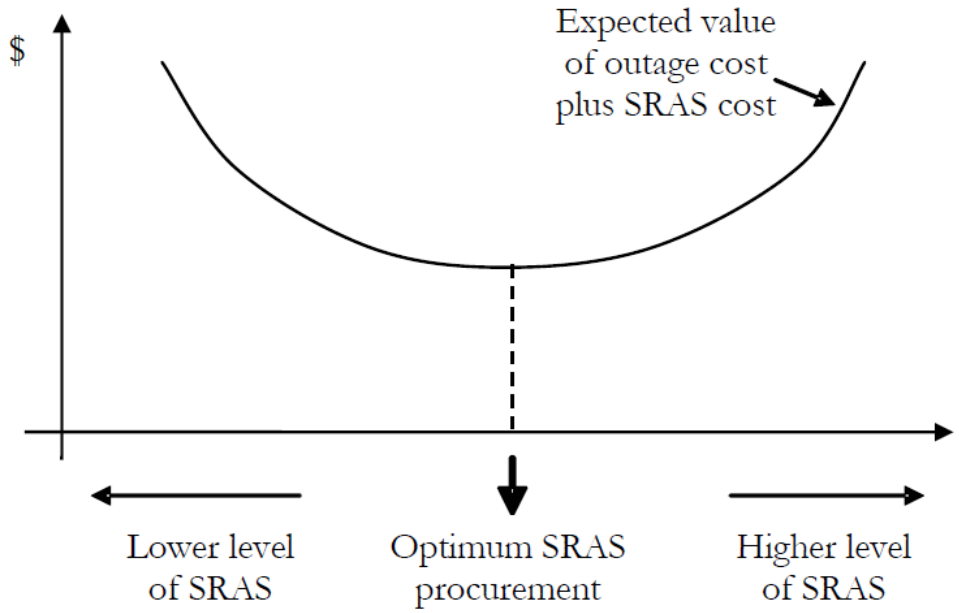
38 Clause 8.8.3(aa)(1) of the Rules.

39 NEL, section 7.

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

weighted marginal benefit of procuring an additional restart service is approximately equal to the marginal cost of procuring that restart service. Figure 3.1 shows this trade-off graphically where the bottom of the curve corresponds to a level of SRAS procurement that minimises the combined total costs of both SRAS procurement and the economic and social cost of a major supply disruption.

Figure 3.1 Optimum level of SRAS Procurement[41]



When determining the Standard that meets the SRAS Objective, the Panel considered an economic assessment of the marginal cost and marginal benefit of each additional restart service to determine the "economically optimal" expenditure on SRAS given the likelihood of a black system event. In addition, the Panel considered the need 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. This is discussed further in section 6.2.

3.2.1 Factors considered by the Panel in the Review

In determining the 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 an achievable and efficient level for the Standard requires an understanding of these technical characteristics, particularly the generating units that provide SRAS.

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

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.

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

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

Reliability of potential SRAS

The procurement of an additional restart service 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 Standard has considered the expected reliability of the potential restart services that are available to each electrical sub-network.

Cost of procuring additional SRAS

The expected price that the market needs to pay to procure additional SRAS will influence the determination of the economically most efficient level of the Standard. Therefore, as discussed in section 5.2.1, the Panel asked AEMO to provide the AEMC staff responsible for providing the Reliability Panel with secretariat services (Panel Secretariat), with advice on the recent offers it has received from potential SRAS providers.

Restoration of load

While the Standard provides 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 Standard, the Panel has considered the timings and expectations for the restoration of load in each electrical sub-network.

3.2.2 Specialist technical advice

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

Technical advice on the Power System

To determine an efficient level for the 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 allowed the economic benefits to consumers of different levels of SRAS procurement to be quantified and compared to the cost of procuring SRAS to determine an efficient level for the Standard. However, the impact of SRAS on the restoration process can vary significantly for each of the electrical sub-networks in the NEM due to the differing technical characteristics of the restart services, the other generation sources and the transmission network.

In addition, the technical characteristics of the sub-network will affect the point in the restoration process where the affected electrical sub-network is considered to have been restarted. This point is at the end of the first stage of the system restoration process, as described in section 2.1.5, when 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. 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 used to restart the system generally provide only a minimal ongoing benefit to the restoration. To address the differing characteristics of each sub-network, and the implications that this has for system restoration, the Standard reflects the time and level of supply to restart the electrical sub-network that is achievable taking into consideration the technical characteristic of that individual 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 Standard that include 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.

Further detail on the advice provided by AEMO is provided in sections 4.2 and 5.2.1.

In addition, the Panel consulted with the JSSCs to identify any regionally specific power system characteristics that it should consider when considering each electrical sub-network.

International comparison of blackouts and restoration

The Panel considers that a review of other regulatory arrangements from other power systems around the world 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. This review is discussed further in section 4.1.

3.2.3 Economic Assessment

As noted above, to determine an efficient level for the 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. To inform this assessment the Panel considered advice provided by AEMO to the Panel secretariat on the differing technical characteristics of the restart services, the other generation and the transmission network.

The Panel recognises that it is difficult to perform an economic assessment to accurately determine an efficient and appropriate level for the Standard. This is because there are so many uncertainties with respect to:

- the time taken to restore supply to consumers from different restart services;
- the time taken to re-connect consumers once supply is restored;
- the reliability of the procured restart services 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 on which the major supply disruption occurs:
- how often major supply disruptions occur and SRAS is required to restart an electrical sub-network; and
- the extent to which stakeholders are risk averse 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 among stakeholder submissions to the issues paper, that the inclusion of an "economic trade off" would provide an improved basis for the Standard and provide stakeholders with increased confidence that the economically efficient level of SRAS procurement that is consistent with the NEO will be maintained.[42]

During consultation, Russ Skelton & associates, representing the views of some generators and major energy users, considered 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.[43] Similarly AEMO noted that "despite the difficulties with quantification, an assessment within a logical, quasi-probabilistic

42 Submissions to the issues paper: AEMO, p.4; ERM Power, p.2; Russ Skelton & Associates, p.35; Snowy Hydro, p.3; Stanwell, p.2.

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

framework could be useful, especially in assessing relative benefits between alternatives being considered."[44]

The Panel agreed and commissioned an economic assessment to inform its determination of the Standard. This assessment considers the trade-off between the cost of procuring different levels 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, when compared with the current one size fits all Standard, recognises the diversity and relative value of different levels of SRAS procurement in each electrical sub-network.

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);
- 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 procurement and expenditure that meets the SRAS Objective given the available information. However, there is a degree of uncertainty surrounding the inputs to this economic assessment as was noted by the Commission in the 2015 System Restart Ancillary Services Rule Change Final Determination:[45]

> "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.

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

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

These costs will also vary substantially between different users, as well as across time."

In accounting for this uncertainty, a key output of the economic assessment of SRAS is the sensitivity analysis which generates a range for the economically efficient level of SRAS procurement based on the expected levels of uncertainty associated with each of the input variables.

Further discussion of the technical advice provided by AEMO for each electrical sub-network as an input to the economic assessment is described in section 4.2 and the methodology and results of the economic assessment, are discussed in chapter 5 and in the Economic Assessment of SRAS report.[46] In response to stakeholder feedback, additional sensitivity analysis was undertaken as a supplement to the economic assessment. The results of this supplementary sensitivity analysis are discussed in section 5.4 and in the Economic Assessment of SRAS – Supplementary Sensitivity Analysis report.[47]

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

47 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services – Supplementary Sensitivity Analysis, 2016.

4 Summary of 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 Standard for the NEM;
- advice from AEMO on the technical characteristics of the potential restart services, generation and network in each electrical sub-network, including the viable restoration paths and expected reliability; and
- a peer review of the technical advice provided by AEMO on black system restoration modelling results for NSW.

An overview of the economic assessment relied on by the Panel to determine the Standard, is described in chapter 5.

4.1 International Comparison of Major Blackouts and Restoration

All electrical power systems need to include some form of black start capability to mitigate the risk of a major supply disruption. In each case, different governance and regulatory arrangements operate in different power systems around the world that include the provision of black start capability. In addition, there have been several major supply disruptions in other electrical power systems recently and it is likely that some valuable lessons could be learnt 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 in determining the Standard, the Panel Secretariat engaged DGA Consulting on behalf of the Panel to undertake an International Comparison of Major Blackouts and Restoration.[48] 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.

48 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[49]
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[50]
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

49 This is equivalent to NEM stage 1 (G_{min}). The stages of the restoration process are defined in section 2.1.5 and G_{min} is defined in section 4.3.1 as the minimum required available generation capacity to support the ongoing restoration of the power system.

50 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 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 Standard.[51] The Panel therefore sought technical advice from AEMO on the technical characteristics of each of the electrical sub-networks, including the capability and reliability of potential restart sources.

51 Clause 8.8.1(a)(1a) of the Rules.

The technical advice provided from AEMO can be divided into advice that is relevant to:

a) the capability of SRAS to contribute to the time and level of the restoration of supply within an electrical sub-network; and

b) the aggregate reliability of potential restart services

4.2.1 Advice regarding the technical characteristics of each of the electrical sub-networks

The technical advice provided by AEMO in relation to the technical characteristics of each of the electrical sub-networks includes:

- restoration curves for different levels of possible restart services;
- the minimum required online and available 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, due to compounding delays.

The restoration curves provided by AEMO for each electrical sub-network are discussed further in section 5.2.1 and shown in full in section 6.5. The remaining network parameters, G_{min}, T_{min} and T_{max}, can be reduced to a numerical figure for each electrical sub-network and are shown in Table 4.2, based on AEMO advice and they were used as technical boundaries in this review.

Table 4.2 Power System Characteristics

Electrical Sub-Network	G_{min} (MW)	T_{min} (minutes)	T_{max} (hours)
Queensland North	825	195	10
Queensland South	825	140	10
New South Wales	1500	85	10
Victoria	1100	140	10
South Australia	330	115	10
Tasmania	300	110	10

These parameters are unique to each individual electrical sub-network and are explained below.

Expected timeframe for restoration of generation capacity[52]

For each electrical sub-network there are a number of potential restart services that may be contracted to provide SRAS. The restoration curves display the estimate for the maximum amount of available generation capacity that could be called on to supply load at a given time during the restoration of the power system for a range of possible SRAS procurement scenarios.

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 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 restoration path for a given electrical sub-network under the assumptions set out in the Standard,[53] given the existing generation and transmission elements in the power system, which can vary between the electrical sub-networks.[54] This time is based on the slowest successful restart service operating correctly. This is explained further in section 6.2.4.

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

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52 This available generation capacity takes into account the limitations of generators, in terms or response times and ramp rates, along with AEMO's assessment of the capability of the transmission network to be progressively energised as part of the restoration process. Further detail on the methodology for determining these restoration curves is provided in the AEMO document "System Restart: Restoration Curves & Generator Reliability", published in October 2016 on the AEMC webpage for this review.

53 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*"

54 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".

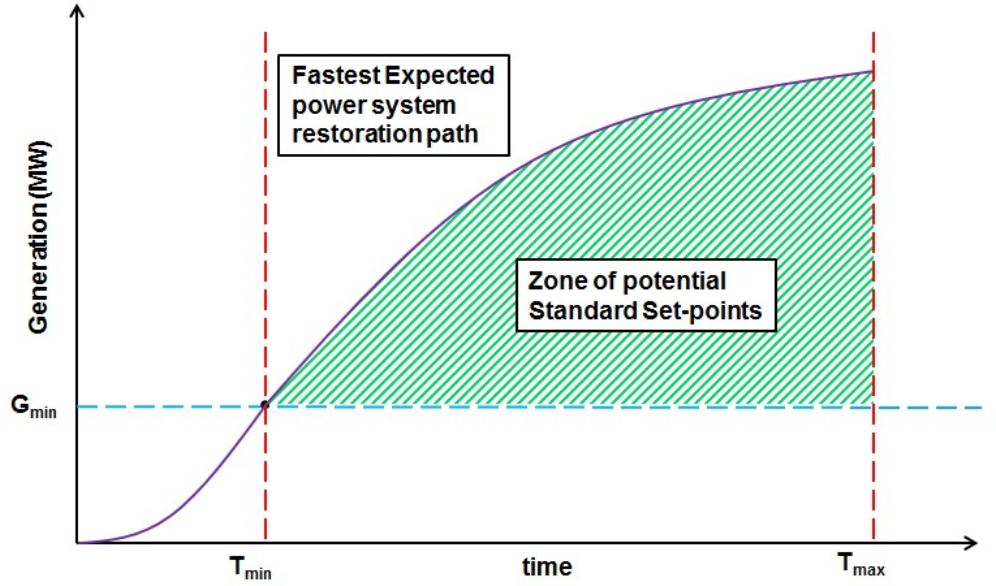
supplies are available and the Standard should aim to complete this stage before T_{max}. Thus T_{max} is treated as a maximum time limit for restoration of generation and transmission above the G_{min} threshold.

Why this advice was necessary?

The Panel sought this technical advice from AEMO because the advice is relevant to the setting of the time and level set points within the Standard.

Figure 4.1 provides a representation of the restoration of supply in a sub-network and hence the 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}. A detailed description of the Panel's rationale for defining the set-points in the Standard is provided in section 6.2.

4.2.2 Advice regarding the reliability of potential restart sources

Under the Rules, the Standard set-points for each of the electrical sub-networks must also include an aggregate required reliability.[55] 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 contracted restart services.[56]

In relation to the reliability of the potential restart services in the NEM, the Panel sought advice from AEMO on its current approach for assessing the reliability of potential

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

56 The requirement for the Standard to include an aggregate required reliability was added by the Commission as part of the SRAS rule change, published in April 2015, to increase AEMO's flexibility when procuring SRAS.

restart services, as well as the reliability of specific restart technologies, such as TTHL.[57] This advice is discussed further in section 5.2.1 and in Appendix D of the Economic Assessment of SRAS Report.[58]

4.3 Peer Review of New South Wales restoration advice

During consultation on the draft determination, stakeholders raised concerns that the restoration curves provided by AEMO for the New South Wales sub-network appeared to be optimistic in terms of the expected performance of generators[59] and the assumptions around potential delays to the restoration process[60] as a result of the complex operational activities that operators would be required to undertake to manage a restoration from a black system event.

Given that the restoration curves are based on confidential data that cannot be made available to stakeholders, the Panel requested that Mal Park of Park Industrial undertake a peer review of the New South Wales generator restoration curves. The goal of this review was to understand whether the curves provided by AEMO were in fact a reasonable representation of the expected restoration performance for the New South Wales electrical sub-network.

On reviewing the restoration curves for New South Wales, Mal Park reached the following conclusion: [61]

> "These restoration curves have been developed by AEMO using scenarios of various combinations of five different SRAS services that could be available for New South Wales. They represent a relatively optimistic but achievable restart process for southern New South Wales and the optimum technical performance from the initial plant connected with the restart process to the north of Sydney.
>
> I consider that the assumptions used for the preparation of these curves to be realistic and achievable. I would expect variations to these curves would only be relatively minor if some delays occurred in some parts of the restoration process. Opportunities exist to cover any poor performance of some individual steps in the process without markedly extending the recovery of supply in NSW."

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57 TTHL is 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."

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

59 Submissions to the draft determination: Russ Skelton & Associates, p.10-12; ERM Power, p.3.

60 Submissions to the draft determination: Russ Skelton & Associates, p.10-12; ERM Power, p.3.

61 Park Industrial: Peer review of NSW Restoration, published on the AEMC website on 15 December 2016, p.8.

This conclusion that the restoration curves provided by AEMO for New South Wales are generally realistic and achievable gives the Panel confidence in this input to the economic assessment of SRAS discussed in chapter 5 and the subsequent determination of the set-points for the Standard discussed in chapter 6.

5 Overview of the Economic Assessment

This chapter describes the economic assessment completed as 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.

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.[62] This assessment considers the trade-offs between expenditure on SRAS and the benefit of a reduction to unserved energy,[63] that is restoring supply to consumers in less time, 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 various levels of SRAS within an electrical sub-network in the event of a major supply disruption that impacts an entire sub-network, based on the probability of such a disruption occurring.

The costs of procuring SRAS in an electrical sub-network are recovered by AEMO from the consumers and generators in that sub-network. The costs of the unserved energy associated with a major supply disruption, ie consumer load not being met, are borne by the consumers in that sub-network. The objective of this economic analysis to minimise the combination of:

- the cost of procuring SRAS, which increases when additional SRAS is procured; and
- the expected cost to consumers of the unserved energy during a major supply disruption, which generally decreases when additional SRAS is procured.

5.1 Economic Assessment Methodology

5.1.1 Benefits of SRAS based on load restoration times

As discussed in chapter 2, when preparing for a potential black system, it is necessary for AEMO to procure restart services that would be capable of energising the network should a black system condition occur. Additional restart services can increase the

62 The Deloitte Access Economics report: Economic Assessment of System Restart Ancillary services in the NEM – Revision 0, published on the AEMC website on 25 August 2016.
http://www.aemc.gov.au/getattachment/6e6ad6c7-584c-4993-98f3-7589fec6b506/Deloitte-Access-Economics-Economic-Assessment-of-S.aspx
A revised copy of this report was prepared by Deloitte Access Economics with additional Glossary definitions and corrections to tables 3.4, 4.4, 5.4, 6.4, 7.4 & 8.4: Economic Assessment of System Restart Ancillary services in the NEM – Revision 1, published on the AEMC website on 15 December 2016.
http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Restart-Standard#

63 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.

speed of the process to restore supply to consumers but may be more than the level of the restart services required to energise the network.

Therefore, the economic benefit of AEMO procuring additional restart services, or restart services that are more likely to operate successfully during a black system condition, is that the load that has been disrupted can be restored more reliably and potentially more rapidly depending on the location of the restart services 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 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 restart services, spread out widely across the electrical sub-network.[64] For example, in New South Wales a restart service in the south and another in the Hunter Valley can effectively restart the New South Wales electrical sub-network, provided both sources operate correctly.[65] If only a single restart service operates then the system restoration would be expected to be successful but would be slower compared to the expected restoration speed when both restart services operate correctly. Procuring more than one restart service 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 backup should the other service not operate successfully, thus increasing the probability that the fastest reasonably practical restoration of generation capacity can be achieved when allowing for the reliability of the individual restart service.

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

- a probability of that combination successfully operating based on the reliability of the individual restart services; and
- a cost of the unserved energy that occurs during the expected time to restore the load, including the costs to individual consumers and the cost to society as a whole of interruptions to services such as water, traffic control and sewage pumping.

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

65 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 the generators in that region.

5.1.2 Summary of approach used by Deloitte Access Economics

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

1. Establish supply restoration curves 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 restart services. These restoration curves are based on the advice provided by AEMO.
2. Quantifying unserved energy (ie consumer demand not met) associated with each restoration curve and quantifying the cost associated with this unserved energy. The costs are quantified by multiplying the unserved energy by the Value of Customer Reliability (VCR) estimate, which was prepared by Deloitte Access Economics based on AEMO's 2014 Value of Customer Reliability Review.[66] The use of VCR as a measure of the value of unserved energy is discussed in further detail in section 5.2.3.
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. That is, the costs of the unserved energy for each of the combinations of restart services are weighted by their probability given the reliability of the restart services.
4. Calculating the annualised marginal benefit of each combination of SRAS plants, by weighting the cost with the probability of a black system event. That is, the benefits of the different combinations of restart services are converted to an annualised value by multiplying by the chance of a black system event occurring and the restart services being used.
5. Establishing the cost of procuring SRAS for each electrical sub-network from the confidential SRAS offers provided by AEMO.
6. Determining the level of SRAS procurement where the probability weighted economic savings accrued from the addition of an SRAS unit are less than the additional cost. That is, where the benefits of procuring a given level of SRAS most closely match the costs of the SRAS procurement.
7. Quantifying uncertainty in the results through a sensitivity analysis where the sensitivity of the results was examined against changes to key variables in the assessment.

5.1.3 Approach to uncertainty used by Deloitte Access Economics

The Panel recognises the economic assessment of the SRAS could be impacted by the high level of uncertainty associated with key variables such as the probability of a black system event that affects a sub-network, the value that consumers and society place on a reliable supply, and the assumed reliability of the individual restart services. Therefore, Deloitte Access Economics was requested to pay attention to the impact of uncertainty

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

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.[67] 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 the probability of a black system event is presented in the Deloitte Access Economics 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 Panel secretariat with technical advice on the operation of SRAS in the NEM and confidential SRAS cost information.

The advice from AEMO that was used by Deloitte Access Economics in 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 restart service procured by AEMO; and
- curves for the restoration of generation capacity in each electrical sub-network for a range of different potential restart service combinations.

This advice and cost information cannot be published as part of the Panel's determination 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);[68] and
- advice on the major load shedding events during the period 1999 to 2015.

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67 Further details on the use of the Frechet, or inverse Weibull, distribution is provided on page 73 of report by Deloitte Access Economics, *The economic assessment of System Restart Ancillary Services in the NEM, 19 August 2016*.

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

This technical advice and cost information provided by AEMO is discussed further in section 4.2, as well as 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 further in section 5.2.3.

5.2.2 Assumptions and constraints

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;[69]
- 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 restart service has been assumed to have an availability of 95 per cent; and
- in order to estimate the costs on consumers of all restart services failing on their initial attempt, it is assumed that when all restart services 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}.[70]

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.[71]

Supply from neighbouring electrical sub-networks is unavailable

The Rules require that the Standard specifies a standard for procuring SRAS under the assumption that supply is not available from any neighbouring electrical sub-networks.[72]

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

70 T_{max} is defined in section 4.2.1 of this determination.

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

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

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.

The Panel made this assumption for the purposes of its economic assessment because the NEM transmission networks generally have sufficient redundancy to provide alternative electrical paths to restart the generating units within the electrical sub-network. In addition, it would be impractical when performing the economic assessment 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 Standard that catered for all possible multiple transmission network elements would be impractical and, if attempted, would lead to very high SRAS costs.

However, 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, as was observed during the black system event that occurred in South Australia on 28 September 2016. Therefore, while it is impractical to include network outages within the economic assessment, as discussed in chapter 6, the Panel included the following two requirements in the Final Standard to be implemented by AEMO to account for network damage:

- the reliability of the individual restart services to include consideration of the reliability of the transmission network components between the restart service and the first transmission substation to which it is connected; and
- the assessment of electrical diversity between the restart services to consider the failure of any single significant transmission element, such as a single line or corridor, that is downstream of the first transmission substation in the restoration path.

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

While the restoration of consumer load is beyond the objective of the Standard, considering the time in which consumer load is restored is an important part of the economic assessment because the benefits associated with SRAS are primarily related to speed at which consumer load can be restored. 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 service provider operations personnel prepare to 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 of the early stages of an actual process to restore consumer load following a black system condition and that applying a uniform assumption provides the consistency necessary to compare the different SRAS procurement and performance scenarios.

In any event, the economic assessment 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. In response to stakeholder feedback on the draft determination, this assumption was investigated further in the additional sensitivity analysis undertaken by Deloitte Access Economics and discussed in further detail in section 5.4.

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 restart services failing to operate. At the end of stage 1 of the restoration process the system has restarted and the restart services are not necessarily required in stages 2 and 3. That is, the SRAS has done its job. Therefore, delays and failures in stages 2 and 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 (and so the setting of the Standard), so such delays have been ignored in the economic assessment.

Availability of restart services

Each restart service has been assumed to have an availability of 95 per cent based on advice from AEMO.[73]

Assumed electrical sub-network restart if SRAS fails

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

- repairs to contracted restart services;
- the potential for other generating units to be able to restart; and

73 This assumption is based on advice from AEMO relating to the historical availability of SRAS capable generators. While a reliability of 95% was used when determining the Standard, AEMO will need to consider overall reliability of each SRAS it procures in order to meet the required level of aggregate reliability in the Standard.

- re-establishment of the transmission network to allow supplies from a neighbouring sub-network.

In theory failure for all restart services 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 placed on the costs to consumers of a failure of all procured restart services so that the incremental benefits of improved SRAS aggregate reliability can be assessed. The report by Deloitte Access Economics refers to this value as the "default blackout duration".[74]

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, as discussed in section 4.2.1.

The impact of this assumption on the economic assessment could be high when considering a single restart service within an electrical sub-network because of the reliance on this single source. However, with the procurement of multiple restart services, the probability of all restart services failing to operate reduces, thus reducing the impact on the economic assessment.

Additional Sensitivity Analysis

In response to stakeholder feedback on the draft determination and economic assessment, the Panel requested Deloitte Access Economics to undertake some additional sensitivity analysis on a number of the inputs and assumptions used for the economic assessment. This additional sensitivity analysis is discussed in section 5.4.

5.2.3 Key parameters for the economic assessment

The key parameters for the economic assessment of SRAS are:

- the estimated probability of a black system event (black system event frequency);
- the estimated value of unserved energy based on VCR; and
- the reliability and availability of potential restart services

A description of each of these parameters is provided below.

Estimated probability of a black system event

As described section 5.1.2, in step 4 of the approach used by Deloitte Access Economics, the cost of a particular restoration scenario is weighted by the estimated probability of a major supply disruption occurring, to derive an annualised cost of black system events. The probability of a black system event was estimated by Deloitte Access Economics

74 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, p.11.

based on a statistical analysis of major historical outages.[75] The probability of a black system event can be expressed as a percentage value representing the chance of a major supply disruption occurring in a given year or as a number of years that may be statistically expected between events. For example, a probability of a black system event of 5.0 per cent is equivalent to a 1 in 20 year event.

Table 5.1 displays the estimated probability of a black system event occurring in each of the electrical sub-networks in the NEM, in the form, 1 in "X" years.

Table 5.1 Estimated Probability of a Black System Event[76]

Electrical Sub-Network	Lower Bound (1 in X years)	Base Case (1 in X years)	Upper Bound (1 in X 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

In recognition of the uncertainty associated with the statistical analysis used to derive the black system event probabilities, the Panel secretariat consulted with each of the JSSCs to validate these probabilities against the best judgement of these representatives most experienced with the particular characteristics of their respective electrical sub-networks. The values shown in table 5.1, represent both the statistical analysis and the views of those most experienced with the operation of their respective electrical sub-networks.

Value of Unserved Energy

As described in section 5.1.2, in step 2 of the approach used by Deloitte Access Economics, the cost of a major supply disruption is calculated by multiplying the associated unserved energy with a value in dollars per kilowatt hour.[77] This value represents the value consumers place on the reliable supply of electricity, or the value that the place on avoiding a blackout.

As part of the economic assessment of SRAS, Deloitte considered a number of methods for valuing unserved energy, including Gross State Product, the Market Price Cap and

75 A detailed description of the statistical approach to determining the probability of a major supply disruption can be found in Appendix C of the Deloitte Access Economics report on the Economic Assessment of System Restart Ancillary Services, 2016.

76 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, 2016, p.8.

77 The value of unserved energy can be expressed equivalently in $/kWh or $/MWh, where $1/kWh is equal to $1,000/MWh.

VCR. These approaches are described in detail in Appendix B of the report by Deloitte Access Economics.

The Gross State Product (GSP) method for valuation of unserved energy uses the annual state based values for GSP, published by the Australian Bureau of Statistics for 2014-15, then divides this by the number of hours in a year and then by the average demand in kilowatts to arrive at an implied value of unserved energy. This assumes that a state-wide blackout effectively brings economic activity in the state to a standstill. However, Deloitte's advice is that this is not actually the case and that GSP is therefore not a true reflection of the value of unserved energy resulting from a major supply disruption.[78] It does, however, provide a valuable benchmark to get a sense of the relative scale of the VCR values produced by AEMO's 2014 review.

The Market Price Cap (MPC) is a limit applied to wholesale electricity prices that is intended to incentivise sufficient investment in generation capacity and demand response to deliver the Reliability Standard.[79] The current market price cap is $14,000/MWh, or $14.00/kWh when expressed in the same units as the VCR. The MPC applies equally across the NEM and does not consider regional variation in economic characteristics that may be expected to drive regional variations in the value that consumers placed on unserved energy. As with the GSP approach, while the MPC provides a useful reference to gauge the scale of the VCR, it is not considered an appropriate method for the valuation of unserved energy associated with major supply disruptions.

Several stakeholder submissions to the issues paper, supported the use of VCR for the evaluation of unserved energy. Russ Skelton and Associates noted that "AEMO's VCR figure is likely to be the best available estimate of consumers' willingness to pay for SRAS."[80] The view that VCR represented a sound basis for the valuation of a major supply disruption was also supported in submissions by the Major Energy Users and Snowy Hydro.[81]

The South Australian Council of Social Services (SACOSS) stated in their submission to the issues paper, that they supported the use of VCR for AEMO's network planning operations. However, the SACOSS submission made reference to a cost assessment undertaken on the major supply interruption due to bushfires in Victoria on 16 January 2007 where it was suggested that indirect social costs may be equal to or in excess of direct costs.[82]

Having considered a number of alternative methods for the valuation of unserved energy, the economic assessment of SRAS undertaken by Deloitte Access Economics concluded that VCR was the preferred method for valuation of unserved energy. In

78 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, 2016, Appendix B, p.65.

79 AEMC Reliability Panel, Reliability Standard and Reliability Settings Review Final Report 2014, p.37.

80 Russ Skelton and Associates, submission to the issues paper, p.35.

81 Submissions to the issues paper: Major Energy Users, p.2; Snowy Hydro, p.3-4.

82 South Australia Council of Social Services, submission to the issues paper, p.3.

order to account for uncertainty around how the VCR incorporates indirect costs associated with widespread and prolonged major supply disruption, an uncertainty range of plus or minus 30 per cent was applied.[83]

Table 5.2 displays the regional and time specific VCR values used to value the unserved energy in the economic assessment of SRAS, along with the respective values for GSP/kWh and the MPC.

Table 5.2 Values for unserved energy: VCR, GSP and MPC[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
Gross State Product[85]	5.82	7.21	7.02	7.08	2.46
Market Price Cap[86]	14.00				

Table 5.2 shows that the VCR is significantly larger than both GSP/kWh and the MPC, with the exception of the 6-12 hour time segment for Tasmania where the VCR drops below the MPC of $14.00/kWh to $13.53/kWh.

Reliability of System Restart Ancillary Services

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 restart service in each of the sub-networks and provide an indication of the relative reliabilities of the available restart services. When multiple restart services are procured the resultant aggregate reliability will be increased. For example if two services with individual reliability of 80 per cent were procured, the resultant aggregate reliability would be 96 per cent (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.

83 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, Appendix B.

84 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, Appendix B, 2016

85 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, Appendix B, p.65. 2016.

86 AEMC, Schedule of Reliability Settings (MPC and CPT for 2016-17) 2016. http://www.aemc.gov.au/News-Center/What-s-New/Announcements/AEMC-publishes-the-Schedule-of-Reliability-Set-(4)

Table 5.3 Average SRAS Reliability and Availability by Electric Sub-Network[87]

Sub-Network	Average Reliability (Start-up Performance)	Average Availability	Average Composite Reliability[88]
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 SRAS procurement 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.[89] 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 restart services. The results show that, for each electrical sub-network, the first restart service 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 Standard in each electrical sub-network. The Panel recognise that the variables used in this assessment are subject to a degree of uncertainty which was considered when the Panel made its determination of the

87 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, Appendix D, p.79, 2016. Note the raw data provided by AEMO.

88 This composite reliability is the combination of start-up performance and availability, as used in the Deloitte Access Economics Report, Economic Assessment of System Restart Ancillary Services. The term "SRAS reliability" as defined in the final standard includes an additional factor in reliability for the reliability of the transmission components between the SRAS source and the first transmission substation to which it is connected. Refer to appendix G for a definition of these terms.

89 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.

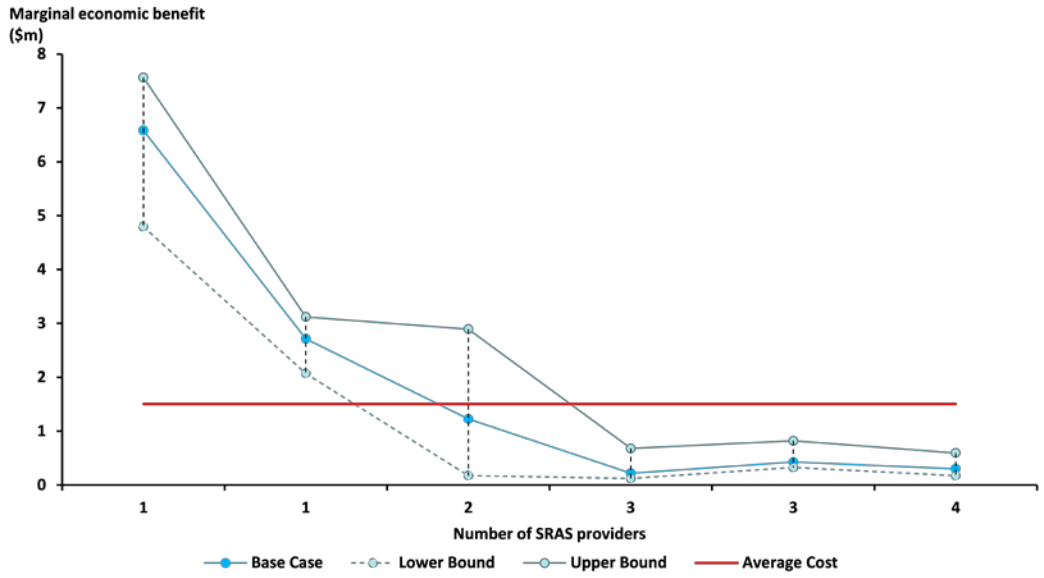
appropriate level of the Standard based on the currently available information in each electrical sub-network.

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 restart services, with a range of between one and three restart services 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 round of SRAS procurement undertaken by AEMO in 2014.

Figure 5.1 North Queensland - Marginal Benefit of SRAS[90]



The North Queensland electrical sub-network is a long radial network, covering a length of 1500kms from north to south. This means that one restart service 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

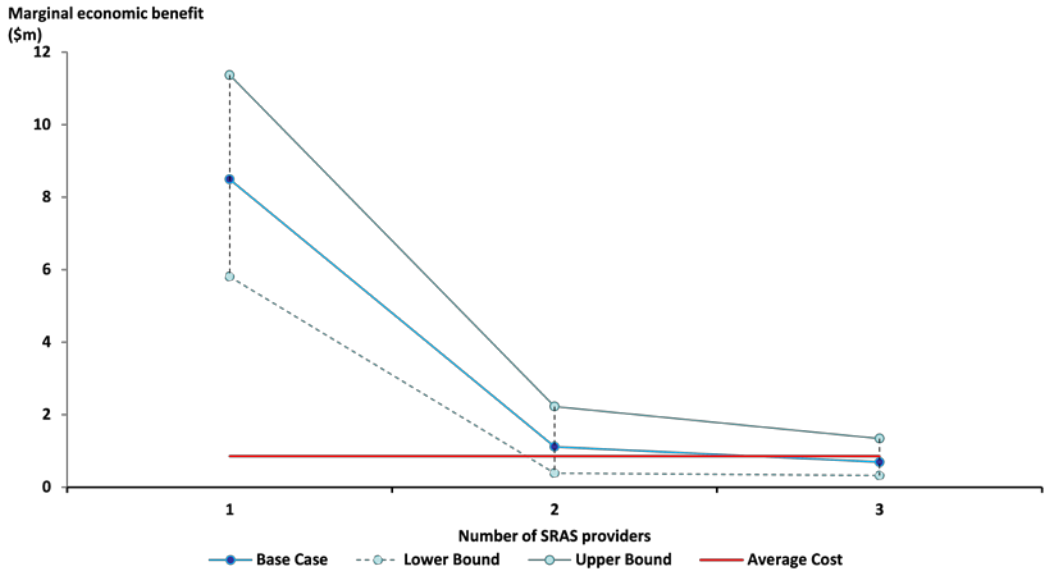
The results of the economic assessment indicate an economically efficient level of SRAS procurement for the South Queensland electrical sub-network to be one restart service, with a range of between one and three restart services when uncertainty is considered.

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

90 Note that the two scenarios labelled "1" and "3" indicate different SRAS configurations.

Queensland sub-network is the comparatively low historical cost for SRAS in South Queensland,[91] with a third restart service 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

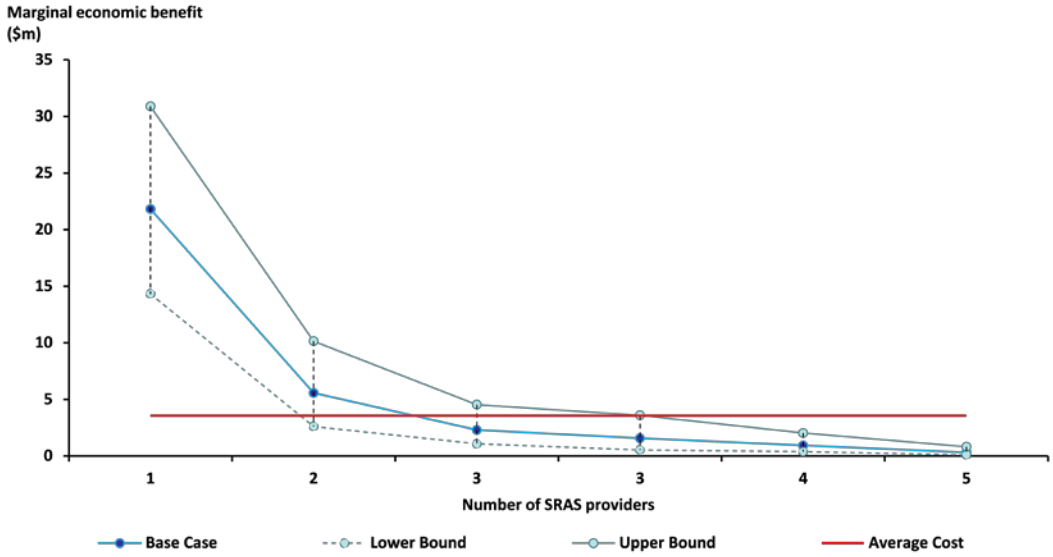
The results of the economic assessment indicate an economically efficient level of SRAS procurement for the New South Wales electrical sub-network to be two restart services, with a range of between one and two restart services when uncertainty is considered.

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

The single SRAS scenario corresponds to a restart service in the south of the New South Wales electrical sub-network. The scenario with two SRAS providers corresponds to one restart service in the south of the sub-network and another to the north of Sydney. A large proportion of the generation in New South Wales is north of Sydney so there is a significant benefit in a restart service near this generation. This is due to the material delay in restoring supply to the auxiliary loads to the generation north of Sydney from when the only restart service is in the south of the sub-network. This is discussed further in section 6.5.3.

91 The average cost for SRAS procurement in SE Queensland in 2015 was $853,507, AEMO 2015 SRAS Tender Process Report

Figure 5.3 New South Wales - Marginal Benefit of SRAS[92]



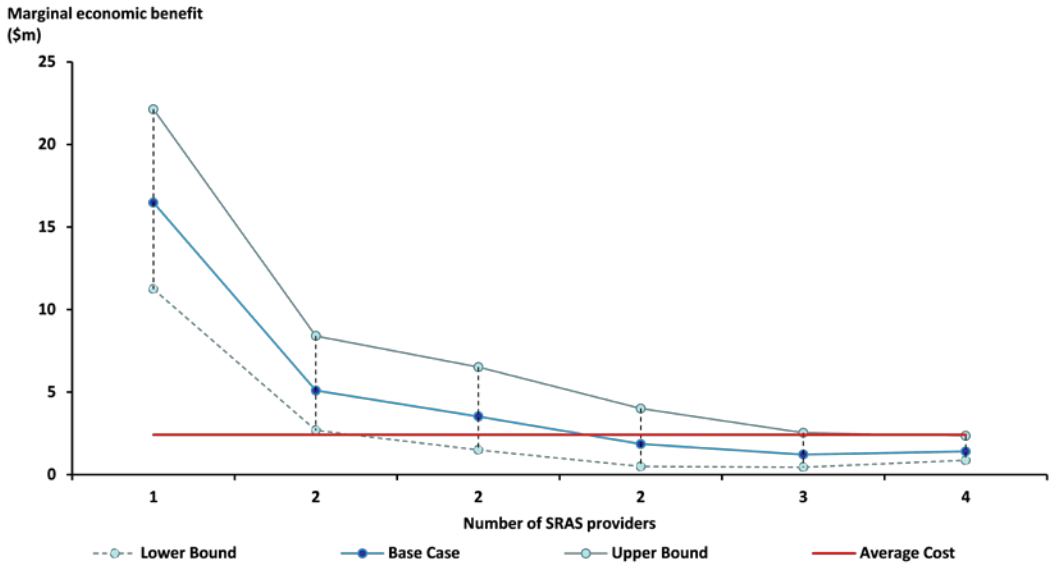
5.3.4 Victoria

The results of the economic assessment indicate an economically efficient level of SRAS procurement for the Victorian electrical sub-network to be two restart services, with a range of between one and two restart services 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 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 restart services providing a net economic benefit.

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

Figure 5.4 Victoria - Marginal Benefit of SRAS[93]

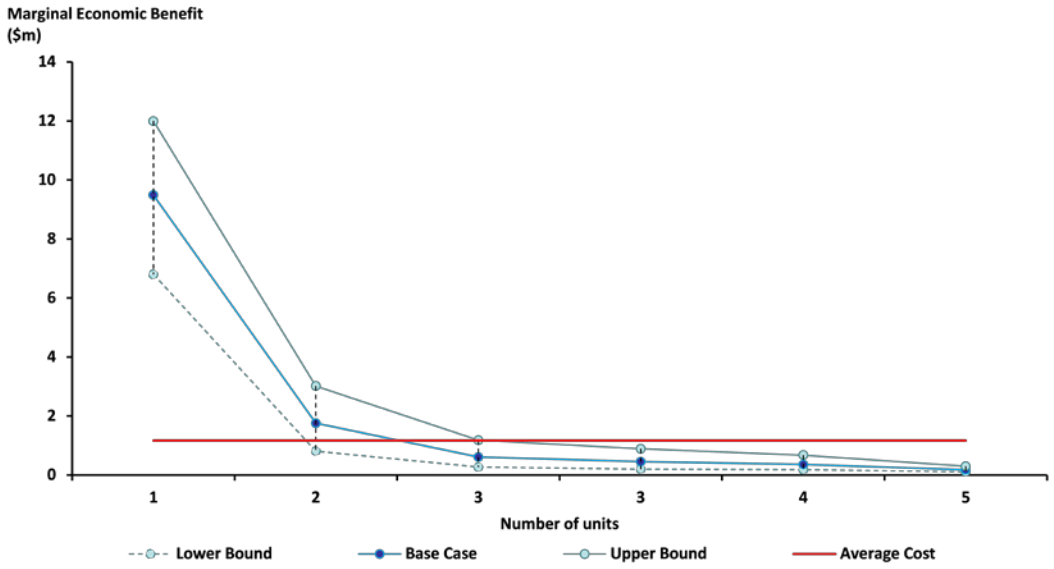


5.3.5 South Australia

The results of the economic assessment indicate an economically efficient level of SRAS procurement for the South Australian electrical sub-network to be two restart services, with a range of between one and two restart services 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 AEMO's 2014 SRAS procurement process. Further analysis of the South Australian probability of a black system event is provided in section 5.4.2.

Figure 5.5 South Australia - Marginal Benefit of SRAS[94]



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

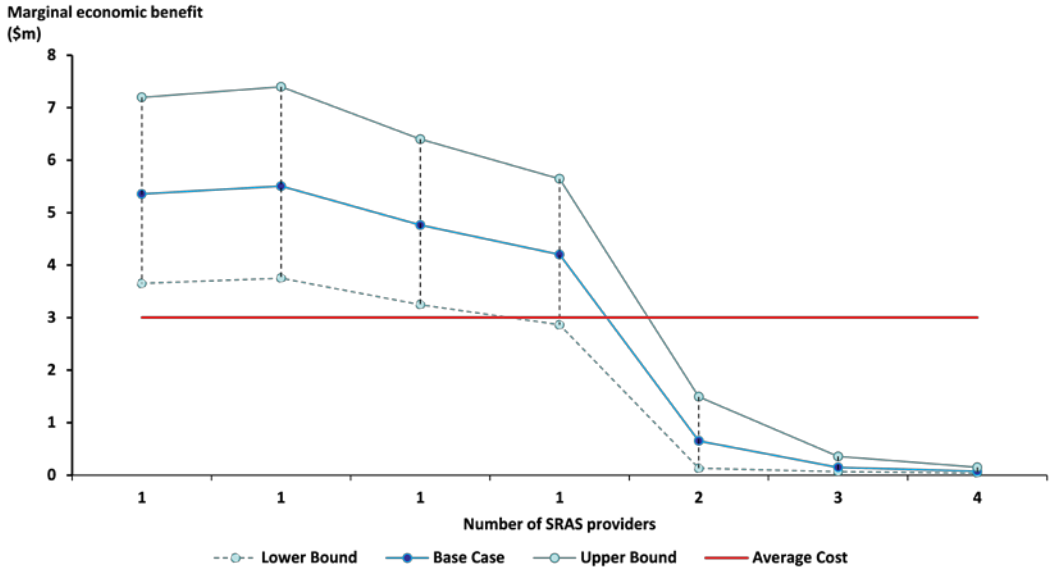
94 Note that the two scenarios labelled "3" indicate different SRAS configurations.

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 restart service, with a range of between one and two restart services when uncertainty is considered. The Tasmanian sub-network is a relatively small power system with predominantly hydro generation that can start relatively quickly.

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

Figure 5.6 Tasmania - Marginal Benefit of SRAS[95]



5.4 Supplementary Sensitivity Analysis

In response to submissions to the draft determination the Panel requested additional economic analysis from Deloitte Access Economics. This section describes stakeholder submissions in relation to the economic assessment completed by Deloitte for the draft determination of the Standard, together with the scope of and results from the supplementary sensitivity analysis.

5.4.1 Submissions to the draft determination

During consultation on the draft determination some stakeholders questioned a number of key areas of the economic assessment including the restoration curves provided by AEMO, the extent to which delays in load restoration were accounted for, the assumption of no network damage and the declining nature of VCR with respect to time.

Both Russ Skelton and ERM Power expressed their views that the restoration curves for New South Wales were optimistic in terms of how fast the available generation capacity is restored and the expected reliability of the restart services following a black system

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

event.[96] Russ Skelton and Snowy Hydro considered that the AEMO restoration curves were generally optimistic and didn't account for potential delays in the restoration process.[97]

Other stakeholders questioned the assumption made by both the Panel and Deloitte, as part of its economic assessment, that the economic assessment for each of the sub-networks should consider restoration curves based on an undamaged transmission network, given that transmission network damage contributed to the black system event that occurred in South Australia on 28 September 2016.[98] With reference to the black system event in South Australia, the Office of the Technical Regulator (OTR) for South Australia requested that the probability of black system event estimates be revised to include this recent event.[99] The estimation of the probability of a major supply disruption, or "probability of a black system event" is based on a statistical analysis over major historical outages, of which there are relatively few in number, thus the OTR noted that addition of the recent black system event in South Australia may change the estimated probability of a black system event for South Australia.

The nature of the VCR used as the value for unserved energy in the economic assessment was raised by other stakeholders. While Energy Australia expressed their support for the VCR values used,[100] a number of other stakeholders expressed concern around the VCR values used. The ENA and TransGrid considered that the VCR used may have underestimated the cost to consumers for prolonged and widespread outages.[101] ERM Power and Russ Skelton & Associates expressed concern about how the VCR Values used decreased over the period from 1 to 12 hours.[102] Russ Skelton expressed a view that the costs associated with a widespread and prolonged outage could be expected to increase over time, or at least remain constant. ERM Power expressed the view that as a widespread outage progresses the VCR would be expected to remain constant or increase due to "loss of water supply and sewage systems, increasing difficulties in transport logistics and food spoilage". ERM Power also suggested that longer duration outages may result in some consumer installing private back-up generation at considerable cost when compared with the communal alternative.

5.4.2 Scope of the supplementary sensitivity analysis

In light of the issues raised by stakeholders in relation to the restoration assumptions for New South Wales, the Panel thought sought supplementary sensitivity analysis to investigate the sensitivity of the results of the economic assessment to variations to

96 Submissions to the draft determination: Russ Skelton & Associates, p.10-12; ERM Power, p.3.

97 Submissions to the draft determination: Russ Skelton & Associates, p.13; Snowy Hydro, p.3.

98 Submission to the draft determination: Electricity Networks Association, p.3; Russ Skelton and Associates, p.13; Snowy Hydro, p.2; TransGrid, p.5.

99 Office of the Technical Regulator for South Australia, submission to the draft determination, p.1.

100 Energy Australia, submission to the draft determination, p.2.

101 Submissions to the draft determination: Electricity Networks Association, p.3; TransGrid, p.8.

102 Submissions to the draft determination: Russ Skelton & Associates, p.15; ERM Power, p.5.

some key assumptions. Therefore, Deloitte investigated the following sensitivity scenarios:

- slower restoration of available generation capacity in New South Wales;
- an additional delay to the restoration of load in New South Wales;
- factoring in the chance of network damage into the SRAS reliability for New South Wales;
- a VCR for each electrical sub-network that is constant over time; and
- the inclusion of the South Australian black system event on 28 September 2016 in the estimation of the probability of a black system event.

The impact of the first three sensitivity scenarios was only investigated for the New South Wales electrical sub-network because stakeholders only raised concerns in relation to the assumptions for the restart of this sub-network.

These scenarios are discussed in further detail below:

Slower restoration of available generation capacity

In order to test the impact of slower increase in restoration of available generator capacity, the restoration curves provided by AEMO for New South Wales were altered to halve the effective ramp rates for each of the contributing generators.

Additional delay to the restoration of load in New South Wales

In order to test the impact of significant delays to the restoration of load over and above the 90 minute delay applied to the economic assessment an additional delay of 120 minutes was applied to the generation restoration curves to simulate delays associated with uncertainty and difficulty in restoring load as part of the black system restoration. The total delay applied to the generation restoration curves to derive the load restoration curves under this scenario was 210 minutes.

Factoring in the chance of network damage into the SRAS reliability for New South Wales

In this scenario a notional transmission network reliability of 80per cent was incorporated into the calculation of the composite reliability for each restart service.[103] This tests the impact of a 20per cent chance that the individual restart services not being capable of operating because of some level of damage to the transmission network.

The resultant composite reliability for each restart service is therefore the product of availability, start-up performance and transmission reliability.

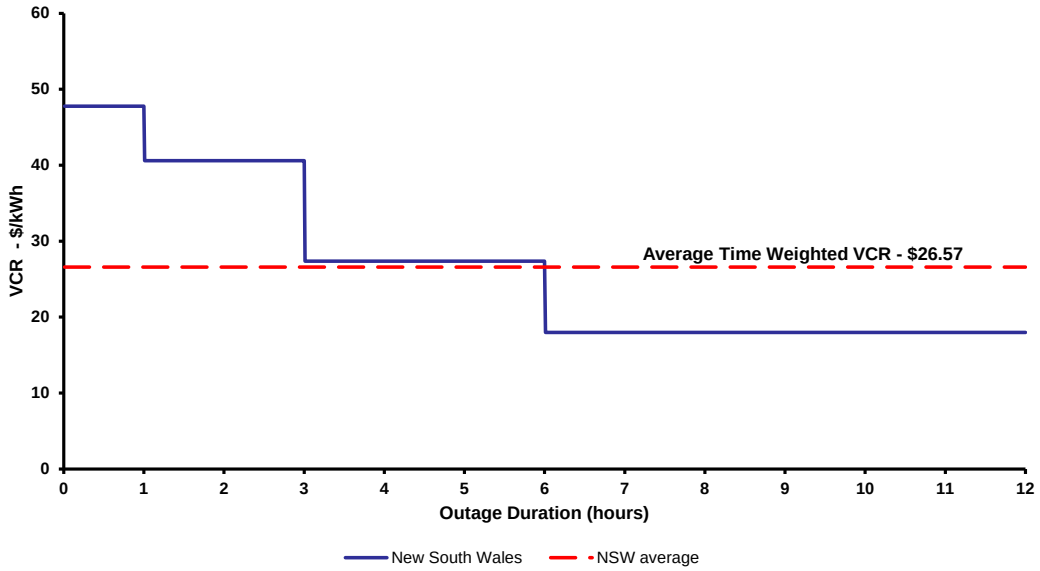
A VCR for each electrical sub-network that is constant over time

To test the impact of a VCR that is constant over the duration of an outage, the time dependent VCR used in the original analysis was replaced with a time weighted

103 The composite reliability for an individual restart service is the overall reliability of the service taking into account the expected start-up performance and availability of that service. For the additional sensitivity analysis the composite reliability of a restart service also includes a factor representing the reliability of the transmission components between the restart service and the first transmission substation to which it is connected.

average value, this can be thought of as a "flat or "flattened" VCR. The flattened VCR has the effect of increasing the value of unserved energy from the six-hour mark onwards while decreasing the value of unserved energy for prior to the six-hour mark. That is, under a flat VCR approach, the value that consumers place on unserved energy does not change with respect to time. This effect is shown graphically using the values for New South Wales as an example, in figure 5.7.

Figure 5.7 Time dependant VCR vs. time weighted average VCR for New South Wales



The sensitivity analysis for New South Wales incorporated the individual and cumulative effects of all of the above mentioned scenarios; slowed restoration of available generation capacity, delayed restoration of load, 80per cent SRAS transmission reliability and flattened VCR. Due to the regionally dependent nature of the VCR values the supplementary economic assessment includes an investigation of a flattened VCR for all the NEM electrical sub-networks to address the concerns of some stakeholders. The original time dependent VCR values along with the time weighted average values for each of the NEM electrical sub-networks are shown in table 5.4.

Table 5.4 Time Dependant VCR and time weighted average VCR values

Outage duration	Queensland ($/kWh)	New South Wales ($/kWh)	Victoria ($/kWh)	South Australia ($/kWh)	Tasmania ($/kWh)
0-1 hours[104]	50.53	47.76	47.57	46.56	34.18
1-3 hours[105]	41.63	40.6	40.47	40.22	31.14
3-6 hours[106]	28.26	27.37	25.96	27.7	21.37
6-12 hours[107]	17.62	17.97	17.00	17.89	13.53
Time weighted average[108]	27.02	26.57	25.70	26.45	20.15

Impact of South Australian black system event on probability of a black system event

As part of the Deloitte supplementary analysis, the estimation of the probability of a black system event was updated to include the black system event in South Australia on 28 September 2016 which resulted in 1895MW of lost load.[109]

5.4.3 Summary of the results of the supplementary sensitivity analysis

The supplementary sensitivity analysis performed by Deloitte showed that the various sensitivity scenarios investigated had different effects on the level of SRAS assessed as economically optimal.[110]

A summary of the impacts of the first 4 sensitivity scenarios, as described in section 5.4.2, is presented below in table 5.5.

104 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services in the NEM, Appendix B, 2016

105 Ibid.

106 Ibid.

107 Ibid.

108 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services – Supplementary Sensitivity Analysis, Appendix A, published on the AEMC website on 15 December 2016. http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Restart-Standard#

109 AEMO, October 2016, Update Report – Black System Event in South Australia on 28 September 2016. Published on the AEMO website on 19 October 2016. https://www.aemo.com.au/-/media/Files/Media_Centre/2016/AEMO_19-October-2016_SA-UPDATE-REPORT.pdf

110 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services – Supplementary Sensitivity Analysis, published on the AEMC website on 15 December 2016. http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Restart-Standard#

Table 5.5 Impact of each sensitivity on the marginal benefit of SRAS for New South Wales – relative to the base case[111]

No. of SRAS for New South Wales	1	2	3	3	4	5
Slower SRAS ramp rates	-13.5%	+0.5%	+7.2%	+9.8%	+30.2%	+46.0%
210 minute delay in restoration	-32.7%	-21.5%	-17.9%	-19.0%	-18.6%	-19.8%
80% transmission reliability	-20.0%	+29.6%	+57.5%	+94.1%	+87.0%	+139.6%
Flat VCR	+33.2%	+36.7%	+24.1%	+29.0%	+8.3%	-0.5%
All sensitivities combined	-34.3%	+30.7%	+78.3%	+118.0%	+133.1%	+220.9%

In interpreting these results, the Panel makes the following observations:

- Halving the generation ramp rate had the effect of reducing the value of the first restart service by 13.5 per cent, but increasing the marginal benefit of the fourth and fifth restart service by 30.2 per cent and 46.0 per cent respectively.
- Delaying the restoration of load by a total of 210 minutes reduced the value of all the SRAS scenarios by between 32.7 per cent for the single restart service scenario to 19.8 per cent for the five restart service scenario. This result can be explained by the considering the effect of the time dependent VCR where unserved energy after 6 hours is valued less than in the early hours of a major supply disruption. The flat VCR sensitivity scenario investigates this effect further.
- The inclusion of an 80 per cent factor for SRAS transmission reliability lowers the composite reliability of each of the restart services. In so doing this reduces the value of the single restart service scenario by 20.0 per cent while progressively increasing the value of each of the additional subsequent restart services by 29.6 per cent for the second restart service through to 139.6 per cent for the fifth restart service. In effect this "spreads" the potential value of SRAS more evenly over the SRAS scenarios.
- Flattening the VCR relative to time increases the marginal benefit for all the SRAS scenarios. The increase is greatest for the first restart service at 33.2 per cent decreasing to 3 per cent for the fifth restart service. The flat VCR increases the value of unserved energy from the sixth hour onwards which has the effect of

111 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services, Supplementary Sensitivity Analysis, 2016.

amplifying any difference between the restoration curves that occurs after the sixth hour.

- When all the sensitivity scenarios are applied in combination to New South Wales the expected economic benefit of the first restart service is reduced by 34.3 per cent, while the marginal benefit of each subsequent restart service is increased, by 30.7 per cent for the second restart service through to 220.9 per cent for the fifth restart service. The progressive increase in marginal benefit when all the sensitivity scenarios are combined is due to the combination of above effects and the amplifying effect on variations from the six hour mark of the restoration due to the flattened VCR.

Impact of South Australian black system event on probability of a black system event

The addition of the recent black system event into the estimation of the probability of a black system event resulted in increased probability of a major supply disruption being calculated for South Australia. As the calculation method used for Tasmania, North Queensland and South Queensland, the estimated probability of black a system event for these electrical sub-networks was also increased for the base case and upper bound.[112] When rounded to the whole numbers the increase is only noticeable for South Australia and South Queensland.

Table 5.6 shows the estimated probabilities of a black system event occurring in each of the electrical sub-networks in the NEM assessed in the economic assessment,[113] revised to take into account, the recent black system event in South Australia.

112 Due to limited available outage data, the method for estimating the probability of a major supply disruption used by Deloitte for Tasmania, North Queensland and South Queensland varied from the other electrical sub-networks. In these electrical sub-networks a "state power law" approach was used to determine the lower bound of the estimated black system event probability range, while the base case and upper bound were derived with reference to the average variance of the lower and upper bounds calculated for Victoria, New South Wales and South Australia. This is described in further detail in section 8 of the supplementary sensitivity analysis report and in Appendix C of the initial report on the Economic Assessment of SRAS by Deloitte Access Economics.

113 See table 5.1 of this determination.

Table 5.6 Estimated Black System Event Frequency - revised[114]

Electrical Sub-Network	Lower Bound (years)	Base Case (years)	Upper Bound (years)
North Queensland	34	30	26
South Queensland	48	43	38 → 37
New South Wales	45	38	31
Victoria	38	34	29
South Australia	20 → 14	18 → 13	17 → 12
Tasmania	25	22	19

As expected, the estimated probability of a black system event in South Australia was increased for the base case as well as for the upper and lower bound. This is shown by a reduction in the estimated time between black system event from 18 years to 13 years for the base case, 20 years to 14 years for the lower bound and 17 years to 12 years for the upper bound.

5.4.4 The Panel's consideration of the supplementary sensitivity analysis

The results of the additional sensitivity analysis undertaken by Deloitte show that where delays to the restoration process, reduced SRAS reliability and a flat VCR are considered the estimated economic benefit of SRAS is spread more evenly across the SRAS scenarios. While the marginal benefit of an additional restart service is increased when these revised assumptions are applied, the change is not significant enough to support a change to the theoretically optimal number of SRAS. This is true for the case of all the sensitivities combined for New South Wales, as it is for the other electrical sub-networks when the impacts of the recent South Australian black system event along with a flat VCR are applied to the economic assessment.

The supplementary sensitivity analysis does not fundamentally change the outputs of the economic assessment, in terms of the optimal level of SRAS for each of the electrical sub-networks. However, in light of stakeholder views on these issues, the Panel has revised sections 4 and 8 of the System Restart Standard to clarify the assessment on SRAS reliability and the treatment of electrical diversity. This is discussed further in section 6.4.3 and 6.8.2.

114 Deloitte Access Economics, Economic Assessment of System Restart Ancillary Services - Supplementary Sensitivity Analysis, 2016. p.22.

6 The System Restart Standard

This chapter outlines the Standard determined by the Panel. The chapter describes:

- the elements of the Standard;
- the set-points for restoration of supply under the Standard in each electrical sub-network;
- the guidelines for AEMO to determine the electrical sub-networks; and
- the arrangements and timing for the implementation of the Standard.

The initial section provides an overview of the key elements of the Standard, followed by a discussion of the Panel's determination for each element of the Standard.

6.1 Overview of the System Restart Standard

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

Box 6.1 Key Elements of the Standard

Time and Level

For each electrical sub-network, AEMO shall procure sufficient SRAS to restore generation and transmission such that supply equivalent to the prescribed level in that sub-network, could be restored within the time defined in Table 6.1 after a major supply disruption occurring. The restoration time represents the target 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.

Table 6.1 also includes in brackets the time and level proposed by the Panel in its Draft Standard. The main changes since the draft are:

- defining the level of the Standard in megawatts (MW), rather than expressing it as a percentage of average demand and rounding up to the nearest 5 per cent; and
- some reductions to the time of the Standard to more closely match the restoration curves provided by AEMO in advice to the Panel, with a margin of an extra 15 minutes plus rounding up to nearest half an hour to increase the range of potential restart services that could be considered for procurement. This margin is to account for the inherent uncertainty of the assumptions used to determine the Standard, and to increase the range of potential restart services to be considered when meeting the Standard. The Panel considers that the size of the margin is not inconsistent with the economic assessment, taking into account the economic and reliability benefits of maintaining a viable depth in the SRAS market.

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

- independently restart, without drawing power from the power system, at

least 500 MW of generation capacity north of Sydney within four hours of a major supply disruption with an aggregate reliability of at least 75 per cent.

Table 6.1 Summary of the set-points for the Draft and Final Standard[115]

Electrical Sub-Network	Standard Level	Restoration Time	Aggregate Reliability
North Queensland	825 MW (Draft Standard of 45 % of average demand)	3.5 hours (Draft Standard of 4.0 hours)	90 % (Draft Standard of 90 %)
South Queensland	825 MW (Draft Standard of 25 % of average demand)	3.0 hours (Draft Standard of 3.0 hours)	90 % (Draft Standard of 90 %)
New South Wales	1500 MW (Draft Standard of 20 % of average demand)	2.0 hours (Draft Standard of 3.0 hours)	90 % (Draft Standard of 90 %)
Victoria	1100 MW (Draft Standard of 20 % of average demand)	3.0 hours (Draft Standard of 3.0 hours)	90 % (Draft Standard of 90 %)
South Australia	330 MW (Draft Standard of 25 % of average demand)	2.5 hours (Draft Standard of 3.0 hours)	90 % (Draft Standard of 90 %)
Tasmania	300 MW (Draft Standard of 30 % of average demand)	2.5 hours (Draft Standard of 3.0 hours)	95 % (Draft Standard of 90 %)

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 Table 6.1. The values of the aggregate reliability are unchanged from the Panel's Draft Standard, except the value for Tasmania has been increased to 95 per cent.

The reliability of any individual restart service will incorporate the expected start-up performance and availability of that service, as well as the reliability of the transmission components between the restart service and the first transmission substation to which it is connected.

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

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

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. The Panel expects this will be set out by AEMO in its SRAS guidelines.

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

In determining the boundaries for electrical sub-networks, AEMO must consider relevant technical characteristics of the power system that best facilitate the achievement of AEMO's power system security responsibility of procuring adequate system restart ancillary services to enable it to co-ordinate a response to a major supply disruption.[116] These technical characteristics would include without limitation the following:

- 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.

Guidelines for assessing the diversity of services

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

- Electrical - diversity in the electrical characteristics shall be considered particularly to account for 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 particularly to account for 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 particularly to account for any single points of failure across the procured SRAS sources for each electrical sub-network.

Following the experience from the South Australian black system event, the Panel included a requirement that when AEMO is accounting for electrical diversity it

116 Clause 4.3.1(p) of the Rules.

needs to consider the redundancy or the failure of any single significant transmission element, such as a single line or corridor, that is downstream of the first transmission substation in the restoration path.

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.[117]

6.2 Determination of the Standard

6.2.1 Set-points for the Standard

The Standard specifies a set-point for each electrical sub-network in terms of:[118]

- a level of generation and transmission capacity 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 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 Standard, the Standard provides guidance to AEMO to procure sufficient restart services from which it expects to be able to restart the power system in each electrical sub-network to the specified level of capability, 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 Standard, the Panel took account of:

- the economic analysis of 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.[119]

117 Clause 8.8.3(aa)(5) of the Rules. While this may appear to be in contradiction with Clause 8.8.3(aa)(2), which states that supply is not available from any neighbouring electrical sub-network. The supply from a contracted restart service for a neighbouring electrical sub-network is an exception that is allowable under the Rules.

118 Section 4.2.1 discusses the requirements for the Standard set-points.

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

- a target level of generation and transmission restoration, equivalent to G_{min},[120] plus an appropriate margin;
- the allowable time to be able to achieve the level of generation and transmission capacity guided by T_{min},[121] plus an appropriate margin; and
- an aggregate reliability determined by the economic assessment of the marginal costs and benefits for the level of SRAS procurement.

Figure 6.1 Generic set-point adopted for the Draft Standard

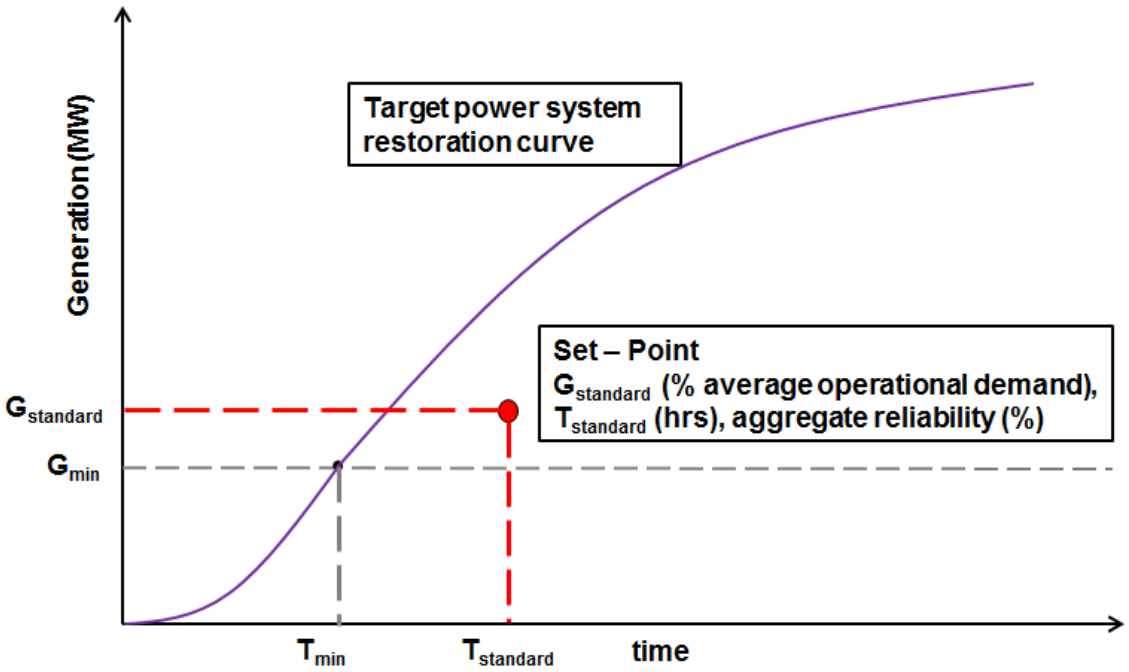


Figure 6.1 shows a generic set-point for the Draft Standard in relation to the target restoration curve[122] and the minimum level of generation (G_{min}). The margins above G_{min} and T_{min} at the Standard set point ($G_{standard}$ and $T_{standard}$) provided the Draft Standard with a level of resilience to minor changes that may occur in the power system while also providing a degree of flexibility to AEMO in applying the Standard. This was considered necessary because the values of G_{min} and T_{min} are based on the current mix of

119 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.

120 G_{min} is defined in section 4.2.1 as the minimum required online generation capacity to support the ongoing restoration of the power system

121 T_{min} is defined in section 4.2.1 as the minimum reasonably achievable restoration time for restoring the available generation to G_{min} in each sub-network;

122 The restoration curves are described in section 4.2.1 and display an estimate of the generator and transmission supply available as a function of time since the commencement of the restoration process.

generation and transmission assets in the relevant electrical sub-network. The Panel recognised 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. In adopting this approach for the setting of the Draft Standard, the Panel sought 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.[123]

The Panel has changed its approach to the setting of the set points in the Final Standard.

Figure 6.2 Generic set-point adopted for the Final Standard

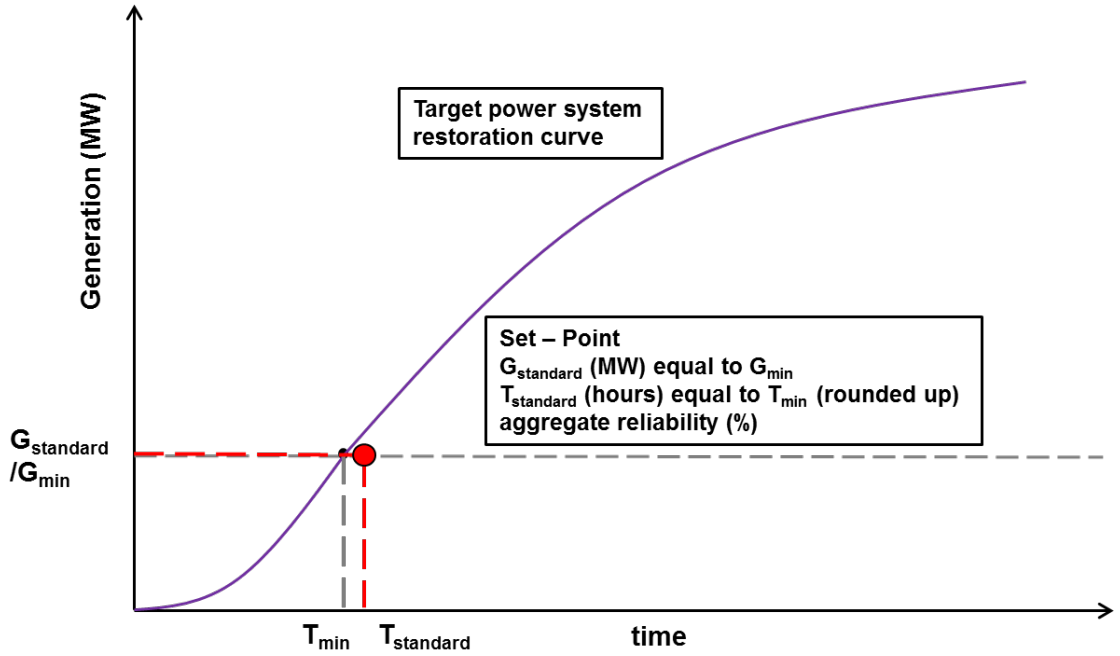


Figure 6.2 shows the generic set-point that the Panel adopted for the Final Standard in relation to the target power system restoration curve and the minimum level of generation (G_{min}). The Panel changed its approach for the Final Standard in two ways:

- defining the level of the Standard in MW (rather than expressing it as a percentage of average demand and rounding up to the nearest 5 per cent); and
- reducing the time in which capability is to be restored to more closely match the restoration curves provided in the AEMO advice to the Panel.

123 The Panel considered 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.

The set-point for the Final Standard no longer includes a margin above G_{min}, but includes a margin beyond T_{min} equal to 15 minutes plus rounding up to the nearest half hour.

The Panel included this 15 minute margin because of the inherent uncertainty of the assumptions used to determine the Standard, particularly the assumed value of customer reliability and the frequency of black system events. The margin also provides a longer timeframe for potential restart services to be considered by AEMO when procuring SRAS and hence would be expected to support increased depth in the SRAS market. The Panel considers that the size of the margin for the set-point is not inconsistent with the economic assessment, taking into account the economic and reliability benefits of maintaining a viable depth in the SRAS market.

The changes to the set-points are discussed further in section 6.3.

6.2.2 The Panel's approach to defining the set-points

The Panel's approach to defining the set-points for the 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.

In accordance with its terms of reference, the Panel has defined the Standard's set points based on the results of the economic assessment performed by Deloitte Access Economics. The Panel also considered the availability of neighbouring sub-networks with inter-connectors[124] that may be able to help in the restoration and the Panel's consultation with each of the JSSCs relating to the estimated probability of a black system event.[125]

The Panel also considered managing the risk of a black system event when determining the Standard, such that the risk of a prolonged major supply disruption 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,[126] along with the range of restoration sources, such as an interconnector to an unaffected electrical sub-network, 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

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124 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.

125 The Panel secretariat consulted with each of the JSSCs to validate these probabilities against the best judgment of these representatives most experienced with the particular characteristics of their respective electrical sub-networks.

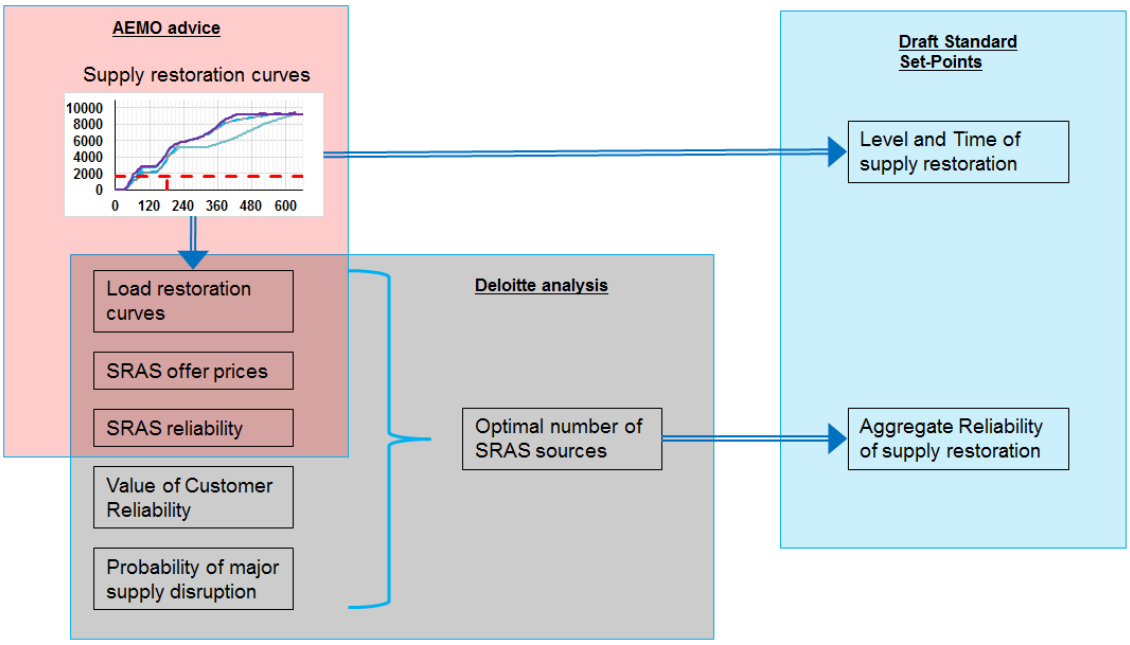
126 While the economic assessment of SRAS focused on the probability and restoration of a black system covering the entirety of each individual sub-network, a black system event may range in size from a part of a sub-network to a whole sub-network or even a NEM wide black system condition. The probability of an event leading to a NEM wide black system condition is extremely small, although recognised as non-zero.

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 Standard in section 6.5.

6.2.3 Determining the Standard based on AEMO's advice and the Economic Assessment

As discussed above, the set-points in the Standard for each of the electrical sub-networks comprise a time in which generation capability must be restored, a level of capability and an aggregate reliability that this time and level is met. These set points of the Standard were determined based on the technical advice from AEMO and the economic assessment described in chapter 5. A summary of how these inputs were used by the Panel to determine the set-points is provided in Figure 6.3.

Figure 6.3 Deriving the Standard set-points from the AEMO advice and Deloitte analysis



The time and level set-points for the Standard depend on the technical characteristics of the electrical sub-network including the speed at which the restart services and other generator technology used in that sub-network can restart and the transmission distances between the various generators and the restart services. As discussed in section 4.2.1, AEMO provided restoration curves for each of the electrical sub-networks in its advice to the Panel. These curves show the impact on the restoration speed of different level of SRAS procurement for each of the electrical sub-networks. AEMO also provided its assessment of the minimum required online generation capacity to support the ongoing restoration for each of the electrical sub-networks, defined as G_{min}. These restoration curves and G_{min} values for the individual electrical sub-networks were used by the Panel to determine the time and level components of the Standard. The determination of the time and level components is discussed further in section 6.3.

The aggregated reliability component of the Standard is determined based on the economic assessment. In particular, the level of the aggregate reliability depends on the number of restart services that the economic assessment suggests will minimise the expected costs of a major supply disruption, to the extent appropriate having regard to the NEO.[127] As discussed in chapter 5, the optimal number of restart services depends on a number of factors including the effectiveness and reliability of the available restart services, the value customers place on avoiding disruptions to their supply and how often major supply disruptions are expected to occur. The aggregate reliability is discussed further in section 6.4.

6.2.4 Illustrating how the set-points were determined for the Final Standard

To understand how the set points for each component of the Standard operate together, and to illustrate the approach the Panel adopted in selecting them, the Panel thought it would be of assistance to provide a generic worked example of a simplified scenario for a sub-network.

For the purposes of the worked example below it has been assumed that:

- the economic assessment showed that two restart services, A and B, would be optimal in terms of minimising the costs of a major supply disruption subject to the costs of procuring SRAS;
- a typical reliability of 80 per cent of the individual restart services independently restarting; and
- the minimum required online generation capacity to support the ongoing restoration of the power system is G_{min}.

In addition, Figure 6.4 shows the assumed restoration curves for:

- both restart services (A & B) operating;
- A operating, with B not operating;
- B operating, with A not operating; and
- neither A nor B operating (referred to in section 5.2.2 as a default blackout).

127 Clause 8.8.3(aa)(1) requires that the Panel determine the Standard in accordance with the SRAS Objective. This is discussed further in chapter 3.

Figure 6.4 Restoration curves for worked example of 2 restart services

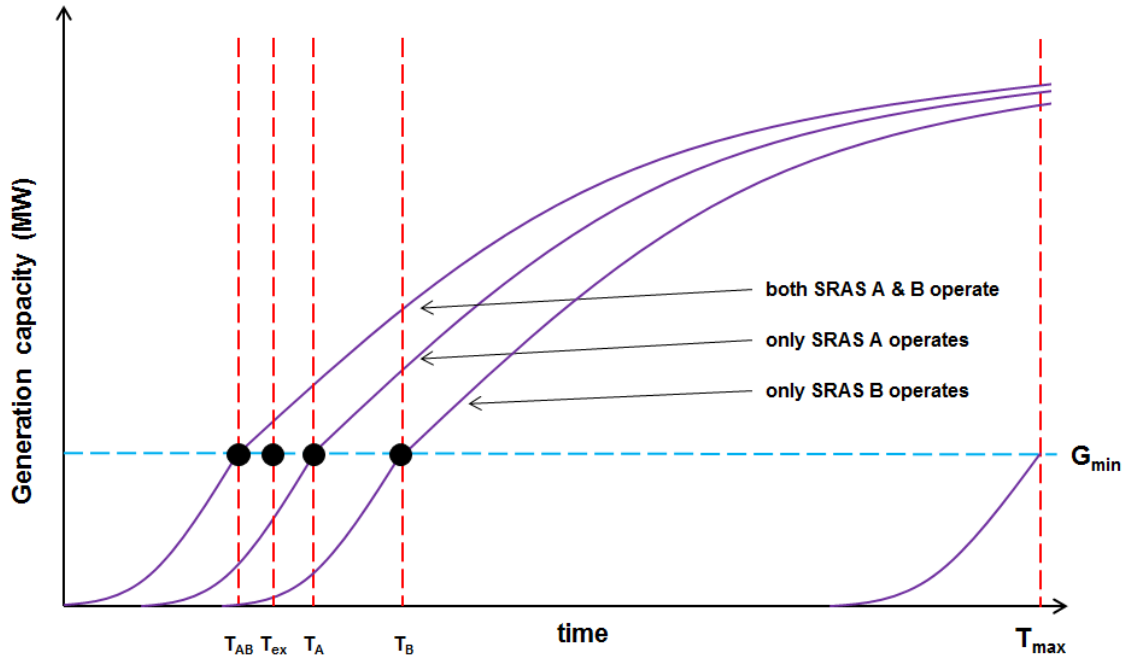


Table 6.2 summarises the probabilities of the different restart services operating associated with this worked example.

Table 6.2 Example Probability Table

Scenario	Probability	Time to reach G_{min}
Both A & B operate	64% (= 80% × 80%)	T_{AB}
A operates only	16% (= 80% × 20%)	T_A
B operates only	16% (= 80% × 20%)	T_B
Both A & B fail to operate	4% (= 20% × 20%)	T_{max}

The restoration curves in the example show that the level of supply would be restored to G_{min} in times T_{AB}, T_A, T_B and T_{max} respectively, depending on which of the restart services A and B operated correctly. The figure also includes the time T_{ex}, which is the probability-weighted average of T_{AB}, T_A and T_B, that is, the mean time of a successful restoration.[128] Thus the time to reach G_{min} is a statistical distribution that depends on the reliability of the two restart services and where the restoration curves reach G_{min}.

When specifying the Standard set-point, the aim is to set a time, level and an aggregate reliability that provides a target that is expected to result in the procurement of the optimal level of SRAS. In the context of this worked example the possible options for specifying the Standard include:

128 In this example $T_{ex} = 0.64\ T_{AB} + 0.16\ T_A + 0.16\ T_B$.

1. a level of G_{min}, a time of T_B and an aggregate reliability of 96 per cent[129] (ie either restart service operates)
2. a level of G_{min}, a time of T_{ex} and an aggregate reliability for restarting of 96 per cent (ie either restart service operates)
3. a level of G_{min}, a time of T_{AB} and an aggregate reliability of 64 per cent(ie both restart services operate)

Each of the three options for expressing the Standard are equivalent for a given set of potential restart services as they each require the procurement of the same restart services in order for the Standard to be met. In each case the Standard represents a minimum technical capability of the procured SRAS, such that meeting or exceeding the Standard would be expected to deliver the economically efficient level of SRAS.

First option

The first option is equivalent to that used by the Panel for the Draft Standard, as described above. That is, a level based on G_{min}, a time based on the slowest successful restoration curve (T_B) and an aggregate reliability based on the probability that at least one restart service capable to meeting G_{min} and T_B would operate.

This approach is straightforward to implement as any restart service that is capable of restarting the electrical sub-network to a level of G_{min} within a time T_B contributes directly to achieving the procurement target and the required aggregate reliability.

The option is broadly consistent with the economic assessment as it would be expected to deliver the efficient level of SRAS procurement in terms of level, time and aggregate reliability. The option also provides a limit for the slowest acceptable restarting time for the procured SRAS, as this is directly specified (T_B in the example).

This option, by specifying the slowest successful restoration time, does not fully capture the different economic benefits to consumers of the faster restoration curves. However, as can be seen in section 6.5, these differences are not very large for most electrical sub-networks, especially given the uncertainty associated with the assumed VCR and frequency of major supply disruptions.

Second option

The second option is similar to the first except that the time set point is based on the expected time of a successful restart. This option is more likely to better align with the economic analysis as it better captures the differences in the economic benefits of all the restoration curves.

The option is, however, likely to be more complicated to implement than the first option and, therefore, makes the resulting standard less intuitive to stakeholders.

In addition, the option does not provide a limit on the slowest acceptable restarting time, other than by specifying the weighted average restarting time. This could become significant if one of the SRAS sources was significantly slower than the others as this would result in a slower restoration if this was the only source that operated.

129 That is 100% minus the 4% probability of all restart services failing to operate successfully.

Third option

The third option specifies a restart time that matches to the most likely time for supply to reach G_{min} if all the restart services operate. This option is similar to the current form of the Standard where restart services that are sufficiently reliable (90 per cent) are able to contribute to meeting the Standard but an actual restoration could be slower than this if any of the restart services do not operate.

While this option appears equivalent to the others it does not provide a limit for the slowest acceptable restarting when only a single restart services operates. For example, if in the future a new restart service becomes available that is fast enough to meet T_{AB} then it could meet the Standard alone and but the overall reliability of a successful restart may be as low as 64 per cent (in this example) which is significantly lower than the level of reliability of 96 per cent expected from two sources.

Option adopted for the Final Standard

Therefore, the Panel has continued to use the approach demonstrated in the first option above for determining the components of the Standard. That is:

- a level equal to G_{min} where the first stage of restoration process is considered to be completed;
- a time based on the when the slowest restoration curve reaches G_{min}; and
- an aggregate reliability for meeting the required level and time.

In addition, the Panel notes that the restoration curves in section 6.5 for the NEM sub-networks are generally relatively close together. Therefore, specifying the time for the slowest restart service would mean that AEMO would in effect be achieving the faster times when it has multiple SRAS available.

6.2.5 Comparison of the form of the Final Standard with the current Standard

Several stakeholders were concerned that the level of Draft Standard is significantly lower than the current 40 per cent of peak demand (in four hours).[130] However, a direct comparison of the set-point time and level between the Final Standard and the current Standard is not possible.

The form of the Final Standard is different to that of the current standard in a number of ways:

- the level is based on a value of G_{min} that is expressed in MW and specific to the electrical sub-network, rather than 40 per cent of peak demand for each electrical sub-network in the NEM which is generally well beyond the level of supply required to restart the sub-network;
- a restoration time based on the maximum allowable time if any of the restart services successfully operates, rather than a restoration time that depends on all the restart services successfully operating; and

130 Submissions to the draft determination: Energy Networks Association, p.3; ERM Power, p.2; Russ Skelton and Associates, p.14,15; Snowy Hydro, p.3.

- an aggregate reliability of 90 per cent (95 per cent in Tasmania) for any restart service to operate, rather than only requiring the individual restart services to have a reliability of 90 per cent.[131]

The level of the current Standard is relatively high compared to the typical demand in most electrical sub-networks. For example, in the 2015/16 year the demand in New South Wales, Victoria, South Australia and Tasmania was often below the current level of the Standard of 40 per cent of peak demand. This implies that the level of generation required to restart the electrical sub-network does not need to be as high as 40 per cent of peak demand. This is reflected in the level of G_{min} provided by AEMO in its advice to the Panel.

The Final Standard set-point times are correspondingly faster than the current Standard of four hours. This is simply because the set-point level is lower and, therefore, would be required to be achieved in less time.

The Final Standard also provides a more meaningful form for the aggregate reliability of the electrical sub-networks, when compared to the current Standard. For example, if as is the case under the current Standard there is no specific reliability for a successful restart (ie reaching G_{min} within the set-point time) and AEMO is required to procure two restart services to provide sufficient capability to meet the Standard then the probability that the specified time and level is met is only about 81 per cent, and this would reduce to about 73 per cent if AEMO requires three restart services to meet the current Standard.[132] However, under the Final Standard the aggregate reliability is the probability that the set-point time and level will be met or exceeded.

The Panel also notes that all the restoration curves shown in section 6.5 show that the level of procurement delivered by the Final Standard is equivalent to that which would be procured to meet the current Standard. That is, where all the restart services procured to meet the current Standard operate correctly the restoration would be expected to achieve a level of supply greater than 40 per cent of peak demand within four hours, with the restoration expected to be slower than this if not all the SRAS operates correctly.[133]

In addition, the level of and time in which generation capacity is to be restored acts as a minimum requirement for the restart services that tender to provide. That is, to be procured, a restart service would need to operate sufficiently fast to either:

- be directly able to restart the sub-network to G_{min} within the time component of the Standard; or

131 The current standard requires that Primary restart services shall have a reliability of 90 per cent and that. Secondary restart services shall have a reliability of 60 per cent. The Final Standard requires that the combined reliability of the procured restart services for a sub-network achieve an aggregate reliability of 90%(or 95% for Tasmania).

132 Based on the requirement in the current standard for a primary restart service to have a reliability greater than 90%. For two restart services the reliability is 0.81 (0.9x0.9) and for three the reliability is 0.729 (0.9x0.9x0.9).

133 While expected level of procurement to meet the Final Standard is broadly unchanged, the inclusion of the required aggregate reliability tightens the likelihood that the required level will be achieved.

- contribute to improving the reliability of another restart service that would meet the time and level components of the Standard.

6.3 Time and level aspects of the set-point

This section discusses the time and level components of the 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 electrical sub-networks. This reflected the requirements of the Rules that applied at the time the Panel last reviewed the Standard.[134] However, following the making of the System Restart Ancillary Services Rule Determination in 2015,[135] the Standard can now vary in each electrical sub-network.[136]

6.3.2 Time requirement in the Standard

The time specified in the Standard for restarting a given level of generation and transmission capability 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, ie 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.

The Panel has considered the time requirements of the Standard and is adopting different values for different regions to reflect the technical system limitations or requirements and economic circumstances that apply in each electrical sub-network. This is discussed in section 6.5.

6.3.3 Level requirement in the Standard

Currently the level of generation and transmission capability specified in the Standard is set such that 40 per cent of peak demand in that sub-network be supplied within four

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

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

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

hours of a major supply disruption occurring. This applies equally in all regions of the NEM.

At the time, 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.[137] This level was not changed when the Panel reviewed the Standard in 2012.[138]

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.[139] The Panel does not agree but considers that the Standard should continue to be specified in terms of a level of generation and transmission network capability. This is because:

- the Rules require that the Standard is specified in terms of the maximum amount of time to restore supply,[140] 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 Rules make it clear that the purpose of SRAS is to restart the power system in the affected electrical sub-network so that further generation can be restarted and so that load can ultimately be restored;[141] and
- the process for reconnecting load 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.

Further the Panel is of the view that the specified level of supply in the 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 4.2.1. For generation to be regarded as contributing to achieving the Standard it would need to be synchronised, or otherwise connected, to the transmission network.[142]

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

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

139 Russ Skelton and Associates, Submission to the Issues Paper, p.2.

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

141 The glossary in chapter 10 of the Rules defines SRAS in terms of restarting large generating units following a major supply disruption.

142 Planning for the restoration of load is managed through the AEMO system restart plan and the relevant NSP black system procedures which are discussed in section 2.5

While the value of G_{min} for a given electrical sub-network is measured in MW, for the purposes of the Draft Standard, the Panel specified the level of generation and transmission as a percentage of average operational demand in that region.[143] This was achieved simply by dividing G_{min} by the value for the average operational demand[144]. 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, rather as a percentage the absolute value of generation is able to reflect changes in the sub-network load over time.

However, for the Final Standard, the Panel has specified the level of generation and transmission capability in MW, rather than as a percentage of the demand in the electrical sub-network. The Panel has adopted this approach because converting to a percentage of demand introduced an arbitrary increase to the level of capability when the value was rounded up to the nearest 5 per cent. Also, the level of supply required to restart an electrical sub-network depends on the quantity and type of generation, and on the characteristics of the transmission network, and not on the levels of consumer demand in the distribution networks within the electrical sub-network.

The Panel has considered the generation and transmission capability requirements of the Standard and has determined different values for different electrical sub-networks to reflect the technical system limitations or requirements and economic circumstances of each electrical sub-network. This is discussed in section 6.5.

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 restart services 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.[145]

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143 AEMO, System restart: restoration curves and generation reliability, published on the AEMC website in October 2016.

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

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

GDF SUEZ Australian Energy (GDF SUEZ) suggested that having this intermediate step provides a degree of transparency that was useful as a guide to both AEMO and potential SRAS providers.[146]

The Panel considers that the potential risk of the intermediate requirement at 1.5 hours could restrict AEMO from procuring some restart services 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 Standard.

6.3.5 Consideration of sensitive loads and energy support arrangements

A number of stakeholders raised concerns relating to the restoration of supply to sensitive loads[147] in the event that such loads are impacted by a major supply disruption. Russ 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.[148] Similarly, TransGrid suggested "the Panel should give consideration to whether the Standard should outline expectations for restoration of sensitive and critical loads within the appropriate timeframe".[149] Russ Skelton and Associates[150] and TransGrid[151] also considered that it was unclear how the loss of a smelter was treated in the Panel's draft determination.

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*;"[152]

The set-points in the 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 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 Standard adequately

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

147 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*."

148 Russ Skelton and Associates, Submission to the Issues Paper, p.27, p.36.

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

150 Russ Skelton and Associates, submission to the Draft Determination, p.15.

151 TransGrid, submission to the Draft Determination, p.8.

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

provides for the economic circumstances of sensitive loads. In the event that an individual customer or customers require an increased level of protection from major supply disruptions over and above that provided to them under the Standard, the Rules allow them to negotiate an energy support arrangement.[153] This would be a contract arrangement between the customer or the associated jurisdiction and either a generator or network business.[154]

Further, as has been noted earlier in the determination, the 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 Standard to outline expectations for restoration of sensitive and critical loads within a specified timeframe. The Panel understands that the restoration of sensitive and critical loads is considered in the development of the TNSP's local black system procedures and AEMO's system restart plan. The issue of communicating the expected timelines for restoration of load in the event of a major supply disruption is discussed further in sections 7.2 and 7.3.

6.4 Electrical sub-network aggregate reliability

This section discusses the aggregate reliability component of the 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 per cent reliability or more; and
- secondary restart service with 60 per cent 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 are no more primary restart services available for use in a particular electrical sub-network.[155]

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 System Restart Ancillary Services Rule Determination in 2015; 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.[156] This change was made to allow AEMO to procure a range of different

153 Chapter 10 of the Rules includes a definition of an energy support arrangement.

154 Clause 4.8.12(f)(2) requires the generator or network business to include the energy support arrangement in the local black system procedures.

155 AEMO SRAS Guidelines, 2014, p.16.

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

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.[157]

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 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[158] and AEMO considered that this would increase the cost but was unlikely to increase the speed of the restoration.[159] Grid Australia and ENA[160] consider outcomes should be based on probability analysis and Russ Skelton and Associates considered that the aggregate reliability should be determined economically.[161]

For the purposes of the Draft Standard, the Panel interpreted the aggregate reliability of the SRAS for an electrical sub-network as the probability that the contracted restart services would be expected to deliver sufficient generation and transmission capability in a sub-network to the specified level within the specified time.

The ENA, ERM, and Russ Skelton and Associates consider that the aggregate reliability of 90 per cent in the Draft Standard too low as it leaves an unacceptable exposure to a failure of the restart services.[162] The Panel does not agree because this is the level of aggregate reliability that is supported by the economic assessment.

The Panel has not made any changes to its interpretation of the aggregate reliability in the Final Standard.

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.

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

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

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

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

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

162 Submissions to the Draft Determination: Electricity Networks Association, p.3; ERM Power, p.6; Russ Skelton and Associates, p.14-15.

This will require AEMO to consider the reliability values of the individual restart services that it procures. In the draft determination the Panel considered that AEMO would 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 included a linkage between the determination of aggregate reliability for each electrical sub-network and the diversity guidelines. In fulfilling this element of the 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.

Some submissions to the Panel's Draft Standard considered that, as well as considering the availability and reliability of the restart service itself, AEMO should also consider the reliability of the transmission network elements associated the restart service.[163] This was further emphasised by the circumstances associated with the black system event in South Australia where the performance of the two contracted restart services was affected by the failure of associated network elements.

Therefore, in addition to the factors listed above, the Panel added a requirement to the Final Standard for AEMO to take into account of the reliability of any transmission components associated with the SRAS up to the first transmission substation to which it is connected.

When implementing the Standard, AEMO is responsible for developing and publishing the SRAS Guidelines.[164] These guidelines will need to be amended following the publication of the Final Standard to include how aggregate reliability will be assessed when AEMO procures restart services. AEMO will need to consult with relevant stakeholders when amending the SRAS Guidelines to include the assessment of aggregate reliability.[165]

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

As discussed in section 6.2.1, the Standard defines a restoration set-point or set-points for each electrical sub-network in terms of:

163 Submission to the draft determination: Electricity Networks Association, p.3; Russ Skelton and Associates, p.13; Snowy Hydro, p.2; TransGrid, p.5.

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

165 Clause 3.11.7(e) of the Rules.

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

The sub-network specific levels in the Draft Standard were based on the values of G_{min},[166] and expressed as a percentage of averaged operational demand and rounded up to the nearest 5 per cent. The level set-points for the Draft Standard are presented in brackets in Table 6.1. The time to restore the relevant level of generation and transmission capability for each electrical sub-network was taken by finding the time intersection for the restoration curves and the level of G_{min}.

As discussed in section 6.2.1, for the Final Standard the Panel determined the time to restore the relevant level of generation and transmission capability to be set as being equal to $G_{min,}$ based on the slowest restoration curve and for the time to restore this level of capability to be stated in MW. These time and level set-points for the Final Standard are presented in Table 6.1.

The Panel selected the aggregate reliability for each electrical sub-network taking account of the economically optimal level of SRAS, as estimated in the economic assessment. The aggregate reliability is an important driver for the number of restart services, as a higher level of aggregate reliability requires AEMO to either procure more reliable or additional restart services 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 restart services, as estimated by Deloitte Access Economics. Table 6.3 provides a summary for each electrical sub-network of the theoretical optimal number of restart services and the aggregate reliabilities these restart services would be expected to provide.

Table 6.3 Range of Aggregate Reliabilities

Electrical Sub-Network	Theoretically optimal number of restart services	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%

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

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 per cent. The Panel considers that this level:

- is not so high as be likely to unduly restrict the potential restart services that AEMO could procure; and
- meets stakeholders' expectations for SRAS reliability, while being consistent with the economic assessment.

The exception is the Tasmanian electrical sub-network where the Panel considers that a higher aggregate reliability of 95 per cent is justified because, unlike any of the other sub-networks, Tasmania cannot rely on restoration from an interconnector following a major supply disruption as Basslink can only operate when the Tasmanian (and Victorian) sub-networks are already operating.

The set-points in the 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 Standard is that restart services shall be procured with the target of restoring generation and transmission capability to a level of 825 MW within three and a half hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90 per cent, 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 restart services and power system.

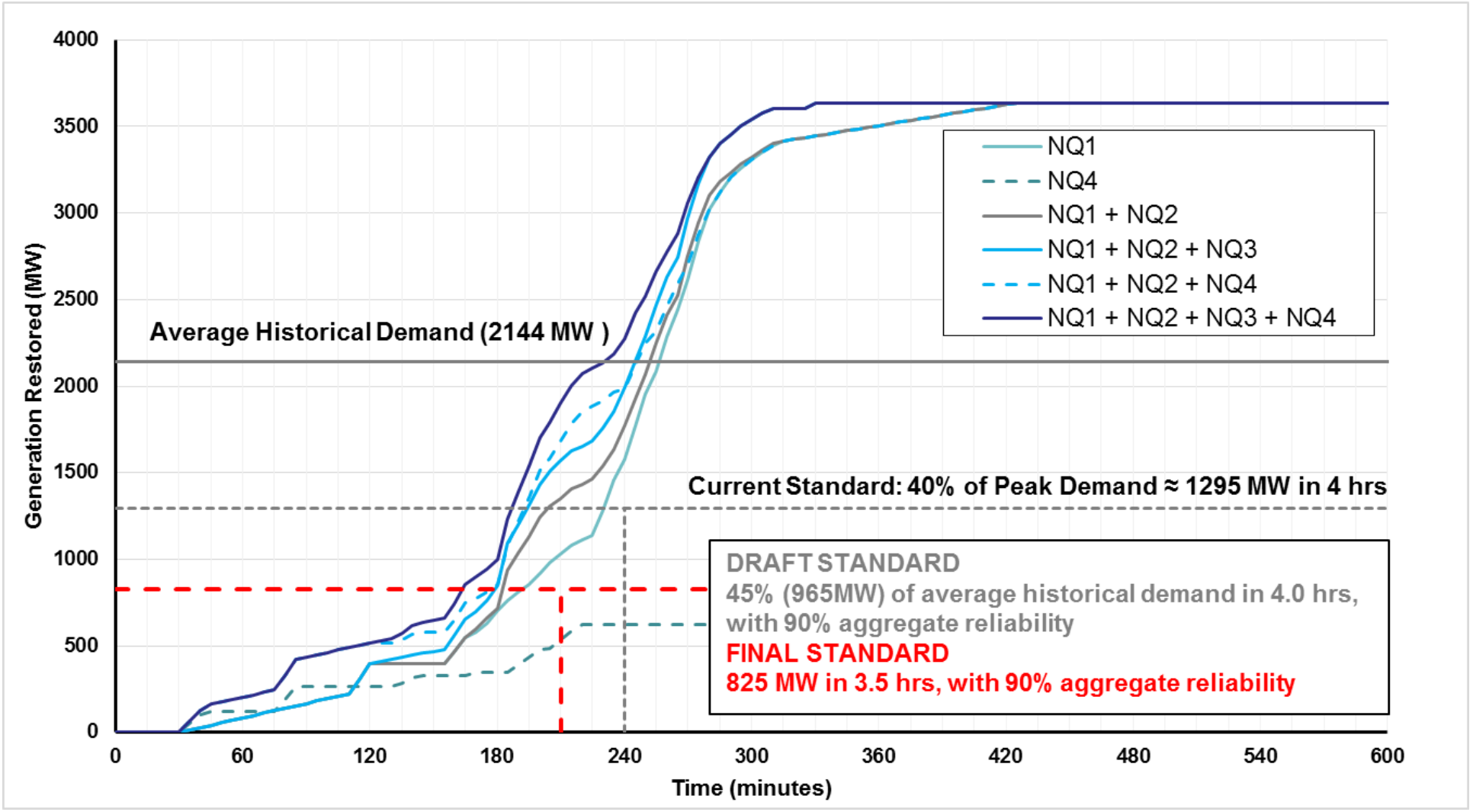
As discussed in section 6.2.1, the time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the North Queensland sub-network the value of T_{min} is 195 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is three and a half hours (210 minutes).

The long distances between the generation centres and relatively low load density in North Queensland, contribute to the longer restoration time of three and a half hours.[167]

167 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 6.5 shows the restoration curves for the North Queensland electrical sub-network, along with the set-points from the current and Standard the system restart standard.

Figure 6.5 North Queensland Standard set-point



6.5.2 South Queensland

The set-point for the South Queensland electrical sub-network in the Standard is that restart services shall be procured with the target of restoring generation and transmission capacity to a level equal to 825 MW within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90 per cent, as discussed in section 6.5 above.

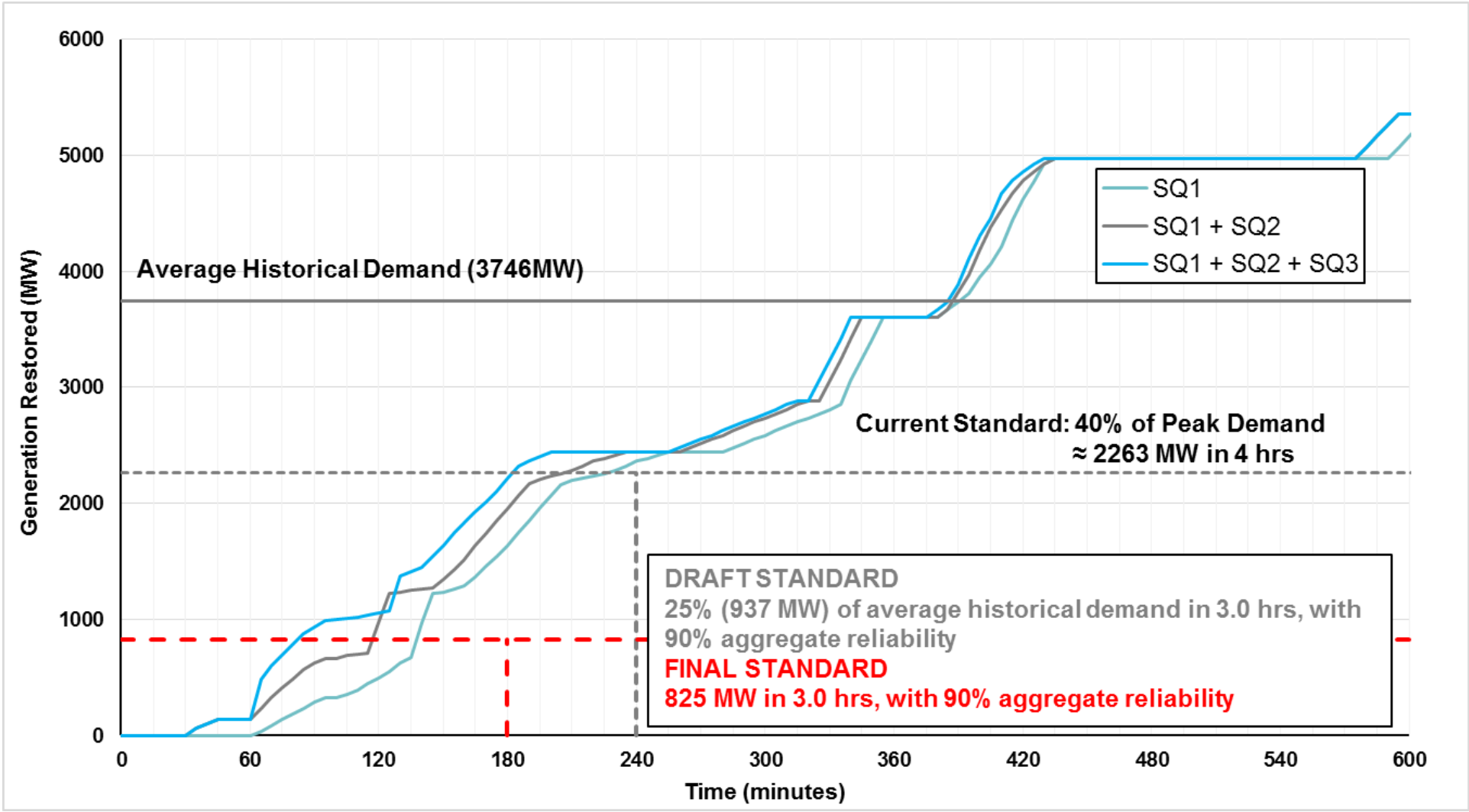
The time and level requirements of the set-point reflect the technical capability and limitations of the available restart services and power system.

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 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 the technical capability and limitations of the available restart services and power system.

As discussed in section 6.2.1, the time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the South Queensland sub-network the value of T_{min} is 140 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is three hours (180 minutes).

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

Figure 6.6 South Queensland - Standard set-point



6.5.3 New South Wales

The set-point for the New South Wales electrical sub-network in the Standard is that restart services shall be procured with the target of restoring generation and transmission capacity to a level equal to 1500 MW within two hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90 per cent, 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 New South Wales electrical sub-network. The time and level requirements of the set-point reflect the technical capability and limitations of the available restart services and power system.

As discussed in section 6.2.1, the time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the New South Wales sub-network the value of T_{min} is 85 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is two hours (120 minutes).

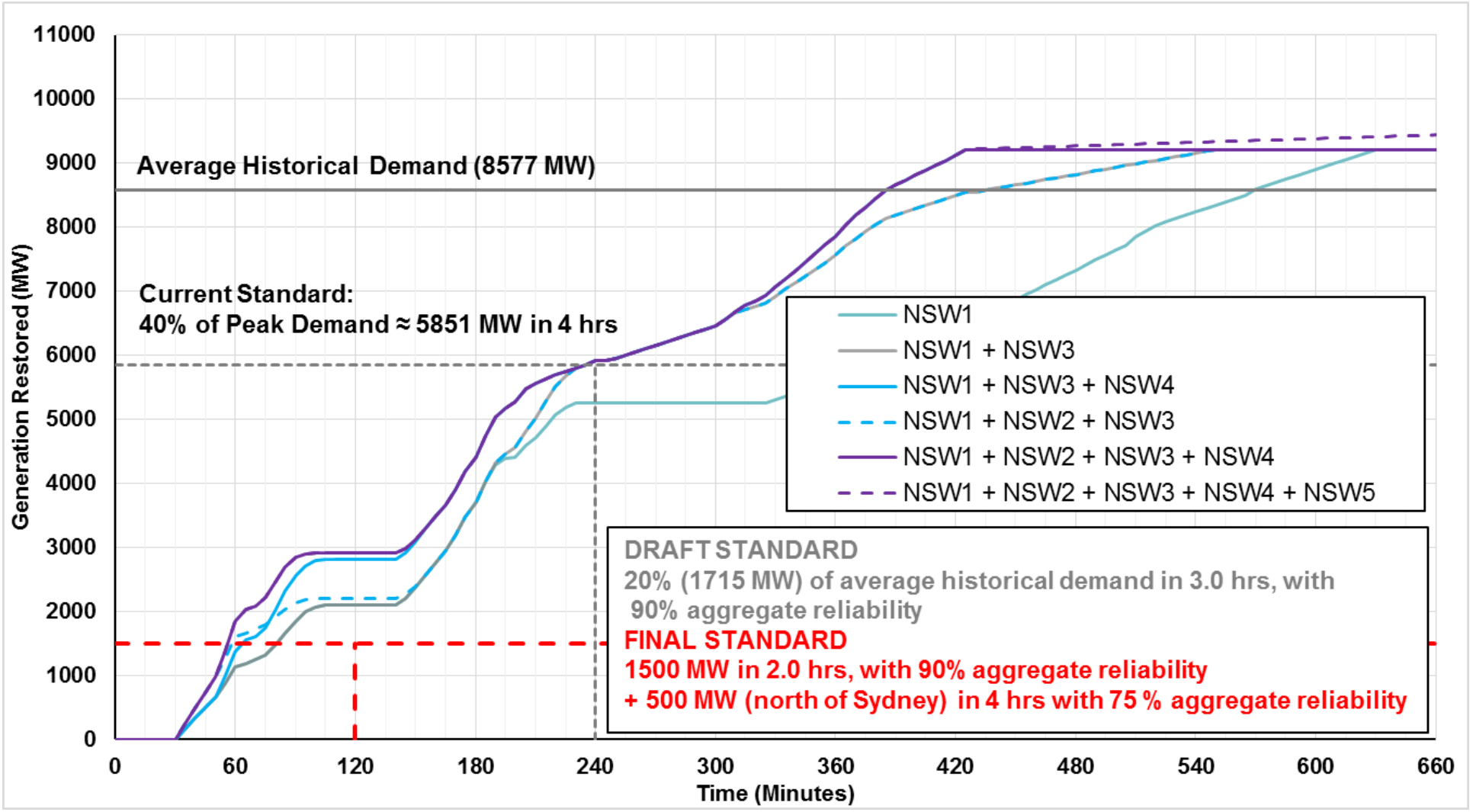
Figure 6.7 shows the restoration curves for the New South Wales electrical sub-network,[168] along with the set-points from the current and Standard. The restoration curve marked "NSW1" corresponds to a single restart service in the south of the electrical sub-network while the curve marked "NSW1 + NSW3" corresponds to one SRAS source in the south and one north of Sydney.[169] The area between these two curves from about 240 minutes to about 600 minutes represents a significant delay to the restoration of supply capability to New South Wales loads which would result in a large quantity of additional unserved energy. This additional unserved energy is due to the absence of a restart service that is close to the generation north of Sydney.

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 Standard for the New South Wales electrical sub-network. AEMO must procure SRAS in New South Wales sufficient to independently restart at least 500 MW of generation capacity north of Sydney within four hours of a major supply disruption with an aggregate reliability of at least 75 per cent. The rationale for this additional requirement is discussed further in section 6.5.7.

168 As discussed in Section 4.3, the Panel engaged Mal Park to undertake a peer review of the restoration curves for the New South Wales electrical sub-network.

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

Figure 6.7 New South Wales - Standard set-point



6.5.4 Victoria

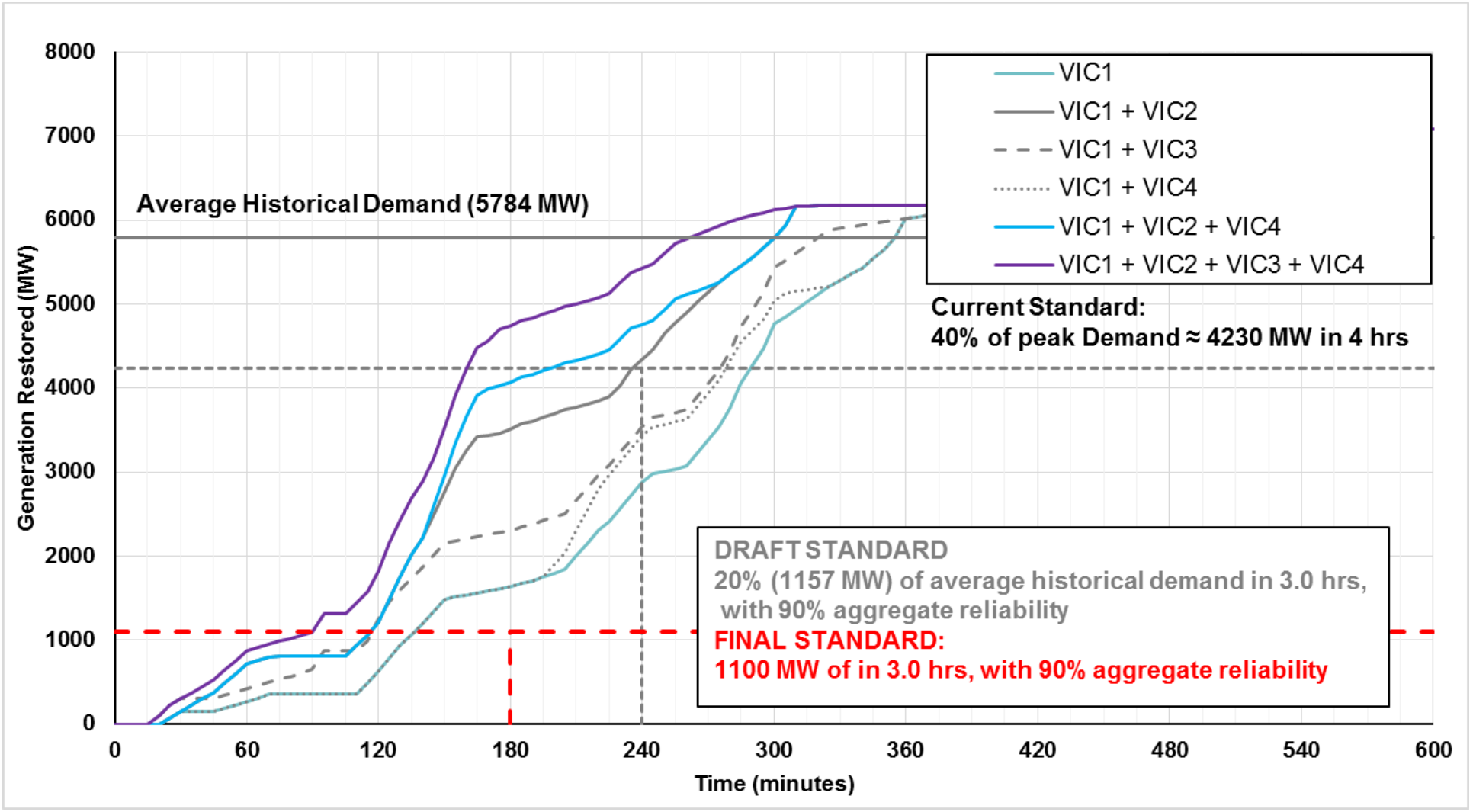
The set-point for the Victorian electrical sub-network in the Standard is that restart services shall be procured with the target of restoring generation and transmission capacity to a level equal to 1100 MW within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90 per cent 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.

As discussed in section 6.2.1, the time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the Victorian sub-network the value of T_{min} is 140 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is three hours (180 minutes).

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

Figure 6.8 Victoria - Standard set-point



6.5.5 South Australia

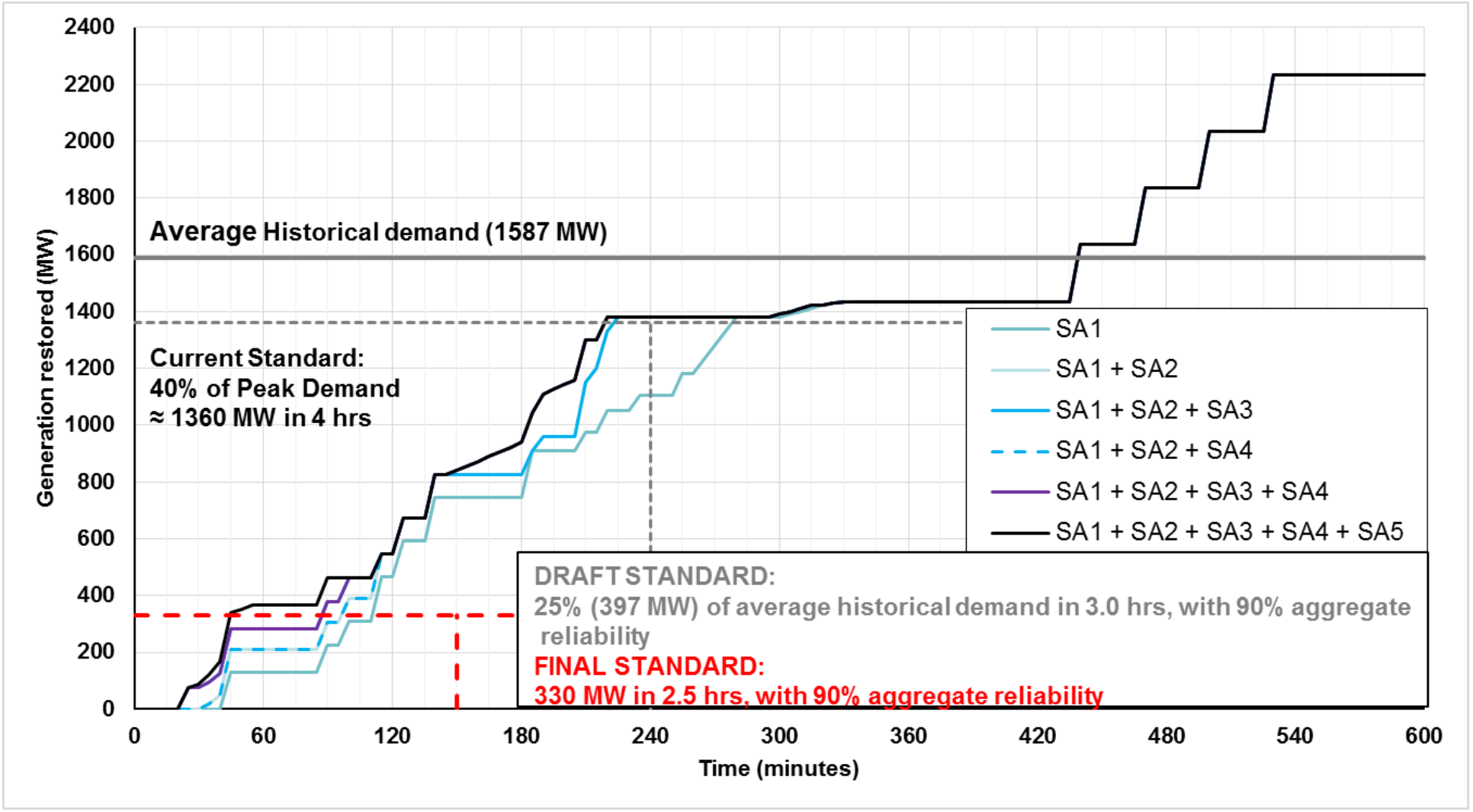
The set-point for the South Australian electrical sub-network in the Standard is that restart services shall be procured with the target of restoring generation and transmission capacity to a level equal to 330 MW within two and a half hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90 per cent, 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.

As discussed in section 6.2.1, the time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the South Australian sub-network the value of T_{min} is 115 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is two and a half hours (150 minutes).

Figure 6.9 shows the restoration curves for the South Australian electrical sub-network, along with the set-points from the current and Standard.

Figure 6.9 South Australia - Standard set-point



6.5.6 Tasmania

The set-point for the Tasmanian electrical sub-network in the Standard is that restart services shall be procured with the target of restoring generation and transmission capacity to a level equal to 300 MW within two and a half hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 95 per cent, as discussed in section 6.5 above. This value is higher than the rest of the NEM because of the increased need for Tasmania to be self-reliant in terms of its restart capability as it is unable to rely on an interconnector as a restart source, as is the case in every other electrical sub-network.

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[170] that can start relatively quickly.[171] The time and level requirements of the set-point reflect this.

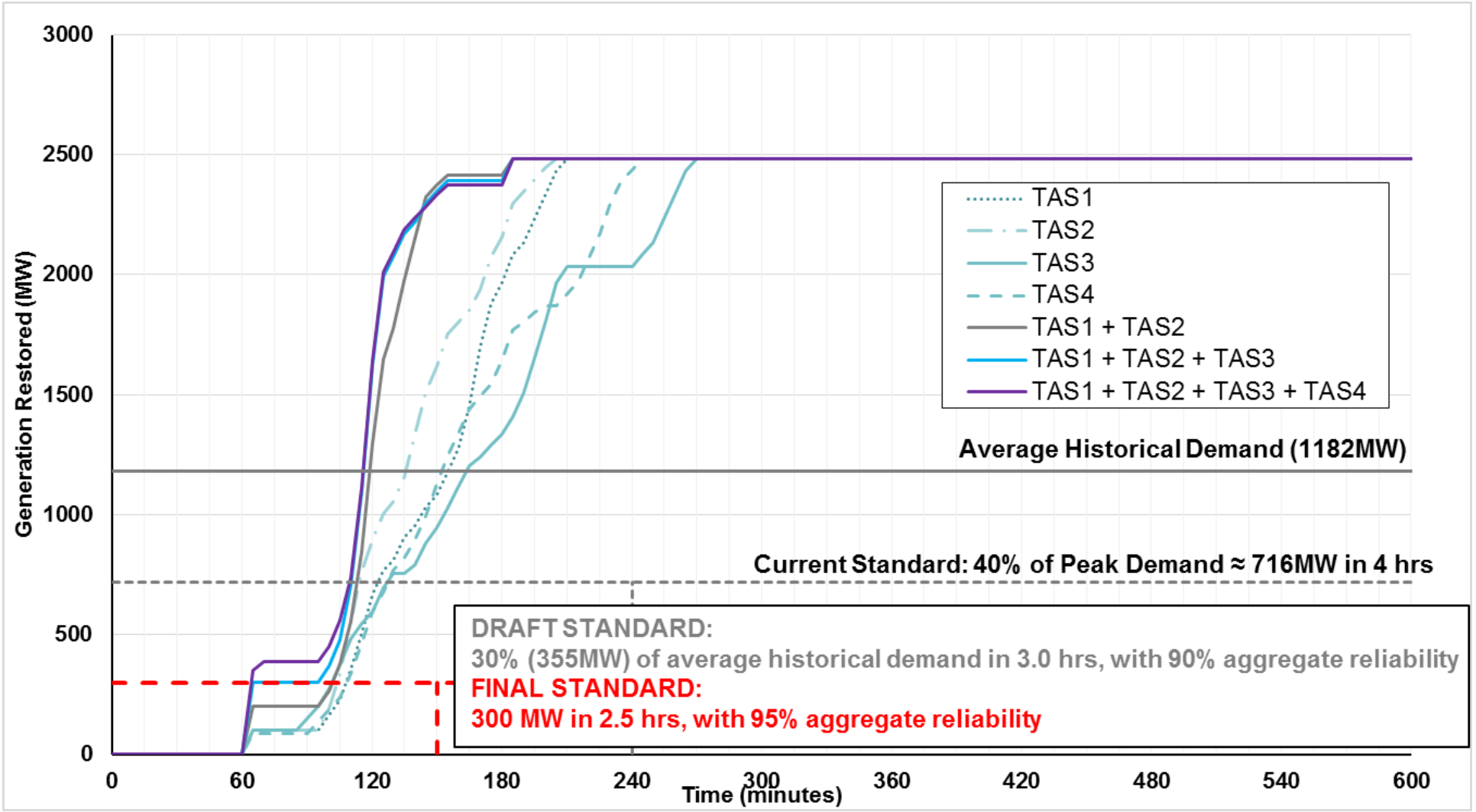
As discussed in section 6.2.1, the time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the Tasmanian sub-network the value of T_{min} is 110 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is two and a half hours (150 minutes).

Figure 6.10 shows the restoration curves for the Tasmanian electrical sub-network, along with the set-points from the current and Standard.

170 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 .

171 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 6.10 Tasmania - Standard set-point



6.5.7 Varying the Standard

The Rules give the Panel the power to vary the Standard between electrical sub-networks to reflect specific technical limitations or economic circumstances.[172] The Panel has included an additional requirement in the Standard for the New South Wales electrical sub-network, to require AEMO to procure SRAS that is sufficient to:

> "independently restart, without drawing power from the power system, at least 500 MW of generation capacity north of Sydney within four hours of a major supply disruption with an aggregate reliability of at least 75 per cent."

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 to 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.[173]

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 restart services, 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 restart service in the Latrobe Valley is relatively small, compared

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172 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"

173 Russ Skelton and Associates, Submission to the Issues Paper, pp 26, 28

to the delays in New South Wales from not having a restart service near the Hunter Valley.

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

The System Restart Ancillary Services Rule Determination in 2015 introduced an ability for AEMO to meet the Standard in one electrical sub-network by contracting a restart service from a neighbouring electrical sub-network provided that a restart service was only contracted to one electrical sub-network at any one time.[174] 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."[175]

The Panel has included this requirement in the 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.[176] 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.[177]

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.

Currently AEMO has determined that there are six electrical sub-networks.[178] These are Queensland North, Queensland South, New South Wales, Victoria, South Australia and Tasmania. With the exception of Queensland, the sub-networks follow

174 AEMC, System Restart Ancillary Services Rule Change, Final Determination, 2015, p.68.

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

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

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

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

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 between each of these sub-networks represent a transmission breakpoint,[179] 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.[180] 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".[181]

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.[182] 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.[183] 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.

AEMO considered that the guidelines for determining the boundaries of the electrical sub-networks should include an objective that AEMO should follow when

179 Ibid, p.5.

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

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

182 Hydro Tasmania, submission to the Issues Paper

183 Clause 3.11.8 of the Rules.

applying the guidelines.[184] In particular, AEMO suggested that a potential basis for such an objective may be the SRAS Objective, that is, "AEMO must use reasonable endeavours to acquire system restart ancillary services to meet the System Restart Standard at lowest cost".

6.7.3 Panel's determination

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.
- 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 factors contained within the current standard relating 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 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:

- 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.

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.

The Panel notes AEMO's view that the guidelines for the determination of electrical sub-network boundaries should include an objective. The Panel considers that the criteria for determining the boundaries for the electrical sub-networks should only relate to the technical characteristics of the resulting electrical sub-networks. The Panel is concerned that adopting an objective that includes minimising the costs of

184 AEMO, submission to the Draft Determination Paper, p.2.

procuring SRAS could result in larger sub-networks with potentially slower restoration times.

The Panel has included additional guidance in section 7 of the Standard to clarify that, AEMO must give consideration to the technical characteristics of the power system when determining the boundaries for electrical sub-networks to facilitate the achievement of its power system security responsibility of procuring adequate restart services for it to co-ordinate a response to a major supply disruption. The Panel considers that this gives AEMO sufficient guidance as it links the procurement of restart services with AEMO's power system security obligation to be able to manage major supply disruptions.

6.8 Diversity and strategic locations

6.8.1 Current requirements of the Standard

The Rules require the Standard to include guidelines for considering diversity and the strategic locations of restart services.[185] 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 electrical diversity requirement requires consideration of whether there would be a single point of electrical or physical failure. AEMO considers that there are always going to be single points of failure during a restart process.[186] 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 restart services 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

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

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

of failure, which should be considered by AEMO during its procurement of SRAS. Therefore, the Panel has clarified the requirement in the Standard for electrical diversity as follows:

> "Electrical - diversity in the electrical characteristics shall be considered particularly to account for any single points of electrical or physical failure across the procured restart services for each electrical sub-network."

A number of submissions on the Draft Standard considered that the assumption of no network damage in planning for a restoration of the power system from a major supply disruption is not appropriate.[187] The Panel considered these submissions along with the advice from DGA on international blackouts and the experience from the black system event in South Australia on 28 September 2016. The Panel agrees that some level of transmission network damage is possible in the event of a major supply disruption and that AEMO requires clear guidance as to the extent of transmission damage that should be considered in meeting the Standard. In order to provide this guidance the Panel has included an additional requirement in section 8 of the Final Standard that:

> "in accounting for the electrical diversity AEMO needs to consider the failure of any single significant transmission element, such as a single line or corridor that is downstream of the first transmission substation in the restoration path."

The Panel considers that this additional requirement, when combined with the requirement for AEMO to consider the reliability of any transmission components associated with the restart services up to the first transmission substation, provides an appropriate balance between ignoring network damage and requiring AEMO to consider every possible combination of network outages when assessing electrical diversity.

Technological diversity

The current technological diversity requirement is intended to mitigate the potential risk that all the restart services 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.[188] Hydro

187 Submission to the draft determination: Electricity Networks Association, p.3; Russ Skelton and Associates, p.13; Snowy Hydro, p.2; TransGrid, p.5.

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

Tasmania also thinks that the current requirement to consider technological diversity is so broad as to offer little guidance.[189]

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 restart services procured for a given electrical sub-network. This is discussed further in section 6.4.

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

Geographical diversity

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

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

Experience from the South Australian black system event on 28 September this year supports the need to continue to require AEMO to consider geographical diversity as the damage to the transmission network was north of Adelaide and left the remainder of the state relatively undamaged.

Energy Source diversity

The current fuel diversity in requirement 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.[190]

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 restart services can demonstrate 12-hour local fuel storage would then this would remove the concern of relying on a fuel supply.[191]

The Panel has amended this requirement 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 as follows:

> "Energy source - diversity in the energy source or fuel utilised by services shall be considered particularly to account for any single points

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

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

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

of failure across the procured restart services for each electrical sub-network."

As discussed in section 6.4, the Standard now requires AEMO to consider diversity as part of its consideration of aggregate reliability of the restart services 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 restart services as part of its SRAS Guideline.[192]

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 minimising the procurement costs (as required by the SRAS objective) while also considering the diversity requirements of the Standard.[193] 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, the Panel has linked the diversity elements to the determination of aggregate reliability covered in section 5 of the Standard.

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 Standard and provides AEMO with improved clarity on how to treat diversity when applying the Standard.

6.8.4 Strategic location of restart services

The Standard is also required to include guidelines for strategic locations of restart services.[194] 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,[195] 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 on the interaction between the Standard and AEMO's SRAS Guidelines, the 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

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

193 AEMO submission to the Issues Paper, p3

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

195 AEMO, SRAS Guidelines, 2014, p16.

section in the 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 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."[196]

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 for 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 Guideline, 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 AEMO to amend the SRAS Guideline, the Standard will take effect on 1 July 2018.

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

7 Additional Recommendations

Throughout the process of reviewing and consulting on the Standard, the Panel has become aware of a number of issues that are not within the scope of the Standard to address, and so fall outside of the scope of its review. They primarily relate to the implementation of the Standard, that is, they relate more generally to the processes for procuring SRAS and for restarting an electrical sub-network following a major supply disruption.

The Panel appreciates that some of these issues are of concern to some stakeholders. However, the Panel does not, under the Rules, have scope to address them. However, it considers that expressing a view on them may help if there is further discussion on these issues. Where it considered appropriate to do so, it has also made recommendations for change, as detailed below. The Panel will monitor the implementation of these recommendations to consider their impact on system security more generally.

7.1 AEMO consultation with TNSPs during procurement process

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

In their submission to the draft determination, the ENA expressed their dissatisfaction with the current SRAS procurement outcomes and recommended that the technical evaluation of the SRAS procurement process be managed by the relevant TNSPs, with AEMO managing the commercial aspect of SRAS procurement.[197] Russ Skelton & Associates suggested that the Panel consult with TNSPs to seek assurance that they are satisfied with AEMO's procurement of SRAS.[198]

The Panel expects that key stakeholders should cooperate with AEMO to resolve differences and avoid confusion around whether sufficient SRAS has been procured. The Panel also notes that the System Restart Ancillary Services Rule Determination in 2015 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 may not

197 Electricity Networks Association, submission to the draft determination, p.7.

198 Russ Skelton & Associates, submission to the draft determination, p.16.

address all 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.

7.2 Development of load restoration plans

While the Standard is only concerned with the restarting of an electrical sub-network following a major supply disruption, it is also important that the entire process for restoring generation and consumer load is effective.

The existing system restart plans cover the first stage of the restoration process following a black system condition, that is, the re-energising of the main transmission network and supplying the auxiliary loads of the major power stations. However, these plans do not cover the full process of returning supply to all consumer loads. Similarly, the network service providers have plans for the restoration of load following a supply disruption. The Panel is not aware of any comprehensive restoration plans that cover the whole of the load restoration from a black system condition.

The Panel recommends that AEMO, the relevant TNSP and DNSPs, as well as the JSSC for each electrical sub-network develop plans for the complete restoration process from a black system condition being declared to the restoration of all consumers' load. The Panel expects that these plans would provide valuable information for the development of state emergency management plans. This load restoration plan would need to describe the general arrangements and expected timelines for major supply disruptions where:

- there is minimal network damage such that all consumers' loads can be re-supplied; and
- a significant proportion of the load cannot be resupplied immediately due to network damage.

In addition, the ENA's submission to the draft determination suggested that the testing regime for SRAS should be more stringent and that preparations for black start restoration include scenario based training.[199] While the Panel supports these suggestions in principle, they are outside of the scope of the Standard and this review. Therefore, the Panel recommends that the development of the load restoration plans should also include simulation and training exercises to test:

199 Electricity Networks Association, submission to the draft determination. p.3, 8.

- the processes required to restore the necessary generation and network elements, as well the consumers' loads;
- the assumptions made by each of the parties that would participate in a sub-network wide restoration process; and
- the communications systems between the various stakeholders.

An important aspect of the load restoration plans is the expected time likely to be required to restore the consumers' loads to different levels should a black system condition occur. The expected timeframe for customer load restoration should be identified in the plans for complete restoration and be validated and informed through regular testing and simulation. This time is likely to be in the form of a range depending on a number of factors including the size of the total load in the electrical sub-network, the physical characteristics of the sub-network such as extent of underground high voltage cables, and when the load is being restored.

7.3 Communication of load restoration timeframes

The Panel anticipates that the expected times to restore the load in an electrical sub-network that would be identified in section 7.2 above would be communicated to the relevant stakeholders within the jurisdiction, and that this communication would be undertaken by the JSSC. To the extent it is not the Panel recommends that the JSSC role be extended to include such a function.

During the review process the Panel became aware that the detailed and involved nature of the system restoration process, and the various roles of the parties involved at each of the three stages, was not generally well understood by many stakeholders. Given the potential significance of a major supply disruption, as evidenced by the black system condition in South Australia, it is important that everyone who has a role understands what can be involved in restoring a system, specifically the unpredictability of the timeframe that can occur between restoring generation and returning supply to consumers within a large distribution network such as a large CBD.

The state emergency management arrangements for the jurisdictions would need to consider the expected time and rate at which the load can be restored so that appropriate preparations can be made. This would include:

- the impact on emergency power supplies at key government and private facilities such as hospitals, prisons, the police and other emergency services;
- the impact on major infrastructure such as water pumping, sewage management, telecommunications, transport (trains and traffic signals); and
- whether emergency food and water supplies are likely to be required.

7.4 End to end testing of restart services

As discussed in section 7.2, the ENA's submission to the draft determination suggested that the testing regime for SRAS should be more stringent.[200]

The Panel understands that the full testing of a restart service can be difficult as it can involve taking transmission elements out of service, which may put some load at greater risk of disruption, and may even require that some loads be disconnection and progressively reconnected during the operation of the restart service.

The Panel recommends that AEMO, SRAS providers and transmission network service providers cooperate more fully to identify opportunities to fully test the operation of restart services when this involves normally in service transmission elements. For example, it may be possible to perform a more comprehensive test of a restart service when the associated transmission elements and/or generation are being returned to service following a planned outage.

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. That is a matter for AEMO. Under the current NEM arrangements, the ongoing compliance with the Standard is a matter for the AER.

In its submission to the draft determination, Russ Skelton and Associates agreed that enforcement of the Standard is a matter for the AER but noted that, due to lack of transparency in relation to AEMO's SRAS procurement process, it was difficult for stakeholders to form a considered view as to whether this issue warranted investigation by the AER.[201]

The Panel agree that it is difficult to completely understand AEMO's procurement decisions because it involves confidential and commercially sensitive information. However, for its most recent round of SRAS procurement AEMO engaged an independent consultant to review its SRAS procurement process, with the objective of providing stakeholders with greater confidence in the SRAS procurement outcomes for the NEM.[202] The Panel supports AEMO's efforts to provide stakeholders with increased assurance of compliance, while maintaining the confidentiality of specific SRAS outcomes.

In its submission to the draft determination, The South Australian Office of the Technical Regulator suggested that the Standard include a requirement for an audit

200 Electricity Networks Association, submission to the draft determination. p.3, 8.

201 Russ Skelton & Associates, submission to the draft determination, p.16.

202 Independent Review of System Restart Ancillary Service Process Improvements – Australian Energy Market Operator, DGA Consulting, 30 June 2015.

and compliance system to provide assurance to relevant stakeholders that AEMO meets the procurement obligations under the Standard.[203]

The Panel considers that including an obligation for AEMO to audit it procurement is out of the scope of the Standard. The Panel also notes that Rules requires AEMO to appoint a market auditor to carry out reviews of such matters that AEMO considers appropriate, including its procedures and their compliance with the Rules.[204]

7.6 Implication of AEMO amending the electrical sub-network boundaries

As discussed in section 6.5, the set-points in the Standard are specific to the current boundaries of the electrical sub-networks. However, the 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 System Restart Ancillary Services Rule Determination, and the Commission considered that "such interactions were manageable through existing processes."[205] 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.

In its submission to the draft report, AEMO proposed that, if the sub-network boundaries change then:

- if a sub-network is subdivided, the new sub-networks could inherit an interim Standard equivalent to the original one; and
- if two sub-networks or parts of sub-networks are combined by AEMO, then the resulting sub-network could have an interim Standard determined by the least onerous combination of parameters from the original sub-networks.[206]

The Panel considers that the current Rules do not allow for an interim Standard where the boundaries of the electrical sub-networks change. In addition, the approach proposed by AEMO may not always work. For example, if an electrical sub-network is subdivided then the two resulting sub-networks may be quite different and require different standards. Similarly, where sub-networks are combined the least onerous standard may deliver less SRAS than would be economically efficient.

Therefore, the Panel considers that a change to the arrangements for changes to the boundaries of the electrical sub-networks would be unlikely to provide significant benefits and is not recommending any changes to these arrangements. As noted

203 The South Australian Office of the Technical Regulator, submission to the draft determination, p.2.

204 Clause 3.13.10(a) of the Rules.

205 AEMC Rule Determination – System Restart Ancillary Services, April 2015, p.70.

206 AEMO, submission to the draft determination, p.3.

above, in the event of any changes to electrical sub-network boundaries, the Panel may, based on a limited review[207] of the Standard as it applies to the affected sub-network(s), determine a revised Standard.

7.7 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.[208] 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 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.[209]

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[210] 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.

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207 The AEMC would provide the Reliability Panel with terms of reference if such a review was required.

208 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.

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

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

7.8 A review of the standards for substation emergency power supply

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

Electrical substations are equipped with emergency power supply equipment, including batteries and sometimes onsite generation, so that the substation can continue to operate during a supply disruption. This emergency equipment 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 substation would no-longer be possible and staff would need to be sent to perform manual switching operations when the substation is eventually energised.

Given that the state of the battery systems in the affected substations may become critical, especially if there is a delay in the restoration process, the Panel recommends that the owners of the major substations 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.

7.9 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.

A The 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 considered in making its determination of the standard in its decision, "AEMC Reliability Panel 2016, System Restart Standard, Final Determination, 15 December 2016". This final 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[211] in that electrical sub-network is restored to the level set out in column 2 of Table A.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 availability of that service, the expected start-up performance and the reliability of the transmission components between the SRAS source and the first transmission substation to which it is connected.

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 A.1 and set out below.

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

- independently restart, without drawing power from the power system, at least 500 MW of generation capacity north of Sydney within four hours of a major supply disruption with an aggregate reliability of at least 75 per cent.

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

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.

7. Guidelines for the determination of electrical sub-networks

In determining the boundaries for electrical sub-networks, AEMO must consider the technical characteristics that would facilitate the achievement of AEMO's power system security responsibility of procuring adequate system restart ancillary services to enable it to co-ordinate a response to a major supply disruption.[212] These technical characteristics would include without limitation 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 incorporate an assessment of the impact of diversity of the services by taking into account the following guidelines:

- Electrical - diversity in the electrical characteristics shall be considered particularly to account for 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 particularly to account for 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 particularly to account for any single points of failure across the procured SRAS sources for each electrical sub-network.

In accounting for the electrical diversity AEMO needs to consider the failure of any single significant transmission element, such as a single line or corridor that is downstream of the first transmission substation in the restoration path.

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

212 Clause 4.3.1(p) of the Rules.

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[213]	2. Level of Restoration (MW)	3. Restoration time (hours)	4. Required Aggregate Reliability
North Queensland	825	3.5	90%
South Queensland	825	3.0	90%
New South Wales	1500	2.0	90%
Victoria	1100	3.0	90%
South Australia	330	2.5	90%
Tasmania	300	2.5	95%

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

B Issues Summary

The tables below provide a summary of the key issues raised by stakeholders in their submissions to the Panel's issues paper and the Panel's draft report, respectively.

B.1 Summary of submissions to the issues paper

The Panel published the issues paper on 19 November 2015, 11 submissions were received from stakeholders. The key issues are summarised below.

Table B.1

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.	• The intermediate step has been removed as

Stakeholder	Issue/Comment	Reliability Panel Response
	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.	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 determined a number of years ago, and the technical characteristics of the power system are now changing due to the continually changing generation mix.	• The Draft Standard includes new set-points for each 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.
Electricity Networks Association (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.

Stakeholder	Issue/Comment	Reliability Panel Response
	• 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 stakeholders to switch emphasis from resolving the issue to recording actions for future legal actions.	• This is beyond the 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 per cent 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

Stakeholder	Issue/Comment	Reliability Panel Response
		discussed in section 6.3.3.
	• A certain percentage of 50 per cent probability of exceedance (POE) peak demand load should be restored within a certain timeframe. For example, 80 per cent 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 per cent of scheduled generators in a sub-network.	• The intermediate step has been removed. This is discussed in section 6.3.4
	• Reliability level should be close to 100 per cent. 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	• The time and level element is maintained in the Draft Standard. This is discussed in

Stakeholder	Issue/Comment	Reliability Panel Response
	Standard, which also enables jurisdictions to assess consumers' satisfaction with the Standard and its risks.	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 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.	• The level of restoration 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	• Noted. This issue relates to the Rules and was addressed in the 2015 SRAS Rule Change.

Stakeholder	Issue/Comment	Reliability Panel Response
	determined the sub-network boundaries.	
	• 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.
Hydro Tasmania	• The current SRAS procurement in Tasmania of 1 unit at 90 per cent reliability (or availability), leaves Tasmania potentially without SRAS for 10 per cent 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 per cent.	• 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	• This is out of scope for

Stakeholder	Issue/Comment	Reliability Panel Response
	the potential for gaming the system to increase prices where there isn't competition.	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 reduce SRAS costs.	• The economic assessment 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 per cent - 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.
Russ 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.

Stakeholder	Issue/Comment	Reliability Panel Response
	• 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.
	• 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 per cent.	• 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 per cent 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.

Stakeholder	Issue/Comment	Reliability Panel Response
	• 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 restoration time.	• The Panel agrees. This is discussed in chapter 5.
	• 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 system procedures 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	• Noted. this is covered in section 5.1.1.

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	does not mean that this historical level of performance would continue into the future.	
	• 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 an outage and immediate costs of SRAS.	• Agreed. This is discussed in chapter 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 per cent 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	• This difference in objectives is clearly defined in the Rules.

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	incentives for long term supply of SRAS.	
	• 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 SRAS.	• This is accounted for in the economic assessment. This is discussed in sections 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 per cent.	• 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.

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	• 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
	• 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 New South Wales, however, there are two natural sub-networks in New South Wales, 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 New South Wales 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	• This concern is discussed in section 7.3.

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	the regional network restoration plans, and	
	— 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 change of the SRAS providers.	• This concern is discussed in section 7.3.

B.2 Summary of submissions to the draft determination

The Panel published the draft determination on 25 August 2016, 12 submissions were received from stakeholders. The key issues are summarised below.

Table B.2

Stakeholder	Issue/Comment	Reliability Panel Response

AEMO	• AEMO provided comment and context on the timing and implementation of the standard. AEMO comment that they feel comfortable with the 1 July 2018 implementation date on the basis that:
	  • the final determination is made in line with current timing expectations; and
	  • it is not necessary for the Reliability Panel to revise the SRS before that date if AEMO changes the boundaries of electrical sub-networks.
		• The Panel understands the lead time required for AEMO to implement the Standard.
		• The Panel will coordinate with AEMO to assist with any transition impacts associated with potential changes to boundaries of sub-networks.

	• AEMO suggest that the standard is expressed to apply to any SRAS procurement undertaken by AEMO after the publication of the standard, in respect of a period commencing on or after 1 July 2018	• The standard is effective from 1 July 2018, as discussed in section 6.9.

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	• There is a need to standardise the terminology used relating to SRAS, AEMO suggest a hierarchy of the following terms and associated definitions:
	  • SRAS Contract,
	  • Restart Service; and
	  • SRAS unit
		• This suggestion has been incorporated into the final determination. Refer to appendix G.

	• The standard needs to provide a clearer objective to guide the determination of electrical sub-networks.	• This is discussed in section 6.7.
	• There is uncertainty in the standard relating to the applicable standard if AEMO were to change the electrical sub-network boundaries. AEMO propose a couple of alternative approaches.	• The Panel has considered the AEMO proposals. This is discussed in section 7.6.
Energy Australia (EA)	• In light of recent events and stakeholder concerns relating to AEMO's restoration modelling, EA support that these curves be reassessed to confirm their validity and modified as deemed appropriate.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment. • Refer to section 4.3 for a summary of the peer review of the NSW restoration curves.
	• EA believe that the assumption to disregard the presence of interconnectors is an extremely conservative one, with reference to international experience and the recent SA black system on 28th September 2016.	• This was considered in making the determination of the Standard, refer to section 6.2.2 & 6.5.
	• EA point out that contracted SRAS may not be the only source of black start capable generation and that other generators with the capability have an interest in facilitating a restoration.	• Noted.

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	• EA believe that the review assessment and outcomes should be carefully examined in light of the recent SA black system event and if changes are required they should be documented for review in a 2nd draft determination and standard.	• In determining the Standard, the Panel has considered the initial learning's from the SA black system event, discussed in section 2.1.4.
	• EA highlight the uncertainty in predicting future SRAS prices and support a stakeholder engagement process that delivers inputs that are as robust as possible.	• Noted.
	• Following on with EA's involvement in the VCR process, EA support the current settings for VCR.	• Noted.
Electricity Networks Association (ENA)	• In response to the AEMO document: "System Restart: Restoration Curves & Generator Reliability – Information Sources and Methodology" , the ENA state that - Generator restoration characteristics should be provided by plant operators, based on actual plant performance corresponding to a black start situation.	• Section 2.3 of the AEMO document outlines the generator performance information provided by Generators to AEMO in the Local Black System Procedures.
	• The ENA recommend that transmission reliability, availability and limitations (thermal, voltage and transient stability) are included in the guidelines and assessment of aggregate reliability of SRAS.	• Transmission reliability is discussed in sections 6.4.3 & 6.8.2. • As discussed in section 7.1, AEMO is required to consult with the NSPs on the capability of potential SRAS providers–.
	• In relation to the Panel's additional recommendations on sub-station batteries - this section should be updated from "battery requirements" to "emergency supply	• Agreed, refer to section 7.8.

Stakeholder	Issue/Comment	Reliability Panel Response
	requirements", to enable a mixture of both diesel backup and battery backup for control, protection, and communication systems to meet the requirement for a minimum period of time, typically 10 hours.	
	• The ENA believe that an increase in extreme weather events will increase the risk of future power system events involving damage to the transmission network.	• Noted.
	• The ENA recommend that the Reliability Panel consider how to address the long term adequacy of SRAS supply within the context of an on-going decline of synchronous generation.	• This is discussed in section 7.7.
	• The ENA believe that preparation for a black system event, including scenario based training could be enhanced.	• This is discussed in section 7.2.
	• The ENA recommend that the Panel instruct AEMO to procure from each TNSP an system restart "training service" to secure a process for highlighting and workshopping the human factors of black start restoration and the particular situations applicable to this special operational case.	• This is discussed in section 7.2.
	• The ENA believe that there is a significant probability that SRAS not co-located with large generation facilities may be unable to provide restart services due to the potential impact of transmission related failures.	• Transmission reliability is discussed in sections 6.4.3 & 6.8.2.
	• In light of the performance of SRAS in restoring the	

Stakeholder	Issue/Comment	Reliability Panel Response
	South Australian power system after the black system event on 28 September 2016, the ENA suggest that an independent technical evaluation of SRAS procurement should be undertaken during the SRAS procurement process. This evaluation should involve consultation with the relevant TNSP and JSSC.	• This proposal cannot be implemented through the System Restart Standard under the current Rules.
	• The ENA state that the testing regime for SRAS should be more stringent to ensure that a contracted level of reliability is met, even under adverse weather conditions. This testing shall include at least energisation of the first section of the transmission network path required to energise a subsequent generation unit.	• This is discussed in section 7.2 and 7.4.
	• The ENA recommend that the commercial and technical aspects of the SRAS procurement process be de-coupled with TNSPs given a leading or review role in the technical evaluation of SRAS procurement proposals and AEMO left to manage the commercial arrangements for contracting SRAS. To support the technical evaluation TNSP's should be required to carry out studies and training to evaluate the expected capability of the proposed SRAS, with the results communicated to relevant stakeholders(generators, DNSP's and large customers).	• This proposal cannot be implemented through the System Restart Standard under the current Rules.
	• ENA members are concerned with the proposed relaxation of the time and level aspect in	• This is discussed in section 6.2.5.

Stakeholder	Issue/Comment	Reliability Panel Response
	the draft standard compare with the current standard.	
	• The events of 28 September 2016 demonstrate two potential failure modes for SRAS and demonstrate the real world difficulty in meeting the current and proposed standards. Therefore reducing the standard restoration target appears counter-intuitive.	• This is discussed in section 6.2.5.
	• The ENA suggest that the required aggregate reliability level of 90% leaves an unacceptable exposure to failure of SRAS of 10%.	• This is discussed in section 6.5.
	• The ENA recommend that TNSP's are empowered to provide greater input on the determination of electrical sub-network boundaries and that the determination of these boundaries be agreed by consensus between AEMO and the relevant TNSP. In the event that that AEMO and the TNSP fail to reach an agreement on electrical sub-network boundaries the Reliability Panel shall appoint an independent expert to mediate a solution.	• The process for determination of electrical sub-network boundaries is defined in the Rules.
	• The ENA observe that the assumption of 100% network availability is presumptuous for a network experiencing a black system event, as it is unlikely that black system event would occur without network damage.	• This is discussed in section 5.4.
	• The ENA note that should critical transmission lines be damaged they will impede the restoration process as was the case in SA on 28 September	• Transmission reliability is discussed in sections 6.4.3 & 6.8.2.

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	2016.	
	• ENA members believe that the adoption of AEMO's VCR for all customer sectors is likely to underestimate the cost of a high impact low probability event for direct-connect customers subject to prolonged outages.	• VCR is discussed in section 5.2.3. and further in section 5.4.
ENGIE	• ENGIE support the Panels approach to setting the standard, on the proviso that the modelling and assumption used to generate the restoration curves can be shown to be robust and defensible.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment. • Refer to section 4.3 for a summary of the peer review of the NSW restoration curves.
	• ENGIE urge the Panel to respond comprehensively to concerns raised by industry experts in relation to the optimistic nature of the restoration curves supplied by AEMO, noting that the restoration time for the SA black system event on 28 Sept. 2016 appeared to take much longer than modelled in the AEMO restoration curves used in this review.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment. • Refer to section 4.3 for a summary of the peer review of the NSW restoration curves.
	• ENGIE agrees that the standard is better expressed relative to operational demand since operational demand is more stable over time than peak demand.	• This is discussed in section 6.2.5.
	• ENGIE is supportive of the Panels approach to aggregate reliability and the requirement that AEMO provide detailed descriptions of the process used to assess aggregate reliability.	• Noted. This is discussed in section 6.4.3.
	• ERM state that the restoration timeframes	• Refer to section 5.4 for a summary of the additional

Stakeholder	Issue/Comment	Reliability Panel Response
	used in the assessment are overly optimistic when compared with historical return to service performance for various coal fired thermal generators. ERM provide historical return to service performance charts for Bayswater, Yallourn, Mt Piper, Vales Point, Loy Yang, Callide and Milmeran in appendix A of their submission along with a summary of return to service times in appendix B.	sensitivity analysis undertaken to supplement the economic assessment. • Refer to section 4.3 for a summary of the peer review of the NSW restoration curves.
	• ERM request clarification as to any assumptions made in the restoration modelling around use of AEMO's power of direction to achieve the system restart standard.	• Refer to AEMO document: "System Restart: Restoration Curves & Generator Reliability – Information Sources and Methodology" and the revised description of assumptions in section 5.2.2.
ERM Power	• ERM supports the general methodology for assessment of the economic value of SRAS, however they question some of the key assumptions and why there was only one source of information (AEMO) and no independent verification process.	• Refer to section 5.2.2 for a description of the assumptions used in the economic assessment and section 4.3 for a summary of the peer review of the NSW restoration curves.
	• ERM present the restoration modelling results for South Australia under the SA1 + SA2 SRAS scenario compared with the "bid availability" of generation following the SA black system event on 28 September 2016. This comparison shows a delay of approximately 5 hours to reach 1000MW restored capacity.	• The default blackout that was assumed by the Panel for the case where no SRAS operates was more conservative than the actual outcome for the South Australian restoration on 28 September 2016.
	• ERM questions whether interconnectors are included in the estimation of restoration curves for South Australia.	• Interconnectors were not included in the AEMO's restoration modelling.

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	• ERM believes that the arbitrary limit of 10 hours as T_{max} has the potential to understate the cost of a black system event and therefore the potential benefits of SRAS.	• This is discussed in section 4.2.2 and 5.2.2.
	• ERM are concerned with the level of explanation for the methodology of determining SRAS reliability and availability as used in the assessment of SRAS, ERM request clarification on this issue.	• This is discussed in section 5.2.3 and definitions included in Appendix G.
	• ERM is concerned with the values for reliability and availability provided by AEMO and used in the economic assessment of SRAS. ERM reference international experience where reliability of trip to house load systems may be in the order of 30%.	• Refer to AEMO document: "System Restart: Restoration Curves & Generator Reliability – Information Sources and Methodology"
	• The South Australian black system event highlights the value of geographically diverse restart services to provide resilience to multiple transmission and generation failures.	• This is discussed in section 6.8.2.
	• While ERM understand the standard as a procurement standard, they recognise that the existing standard is often misinterpreted as a standard for the restoration of load. ERM suggest that the final determination and revised standard provide greater clarity on this issue.	• This is discussed in chapter 2.
	• ERM request that the Panel provide additional clarity with regards to the generation mix for the power systems documented in the DGA consulting report - International Comparison	• The Panel does not consider that this information is relevant to the determination of the Final Standard for the NEM.

Stakeholder	Issue/Comment	Reliability Panel Response
	of Major Blackouts and Restoration (May 2016).	
	• ERM notes the relative reduction in the level of restoration within a given time in the draft standard and that the larger electrical sub-networks of NSW and Victoria are reduced the most, in the order of 60% as a MW value, relative to the existing standard.	• This is discussed in section 6.2.5.
	• ERM are happy with the inclusion of aggregate reliability in the draft standard, however urge the Panel to consider raising the required aggregate reliability from 90% to 95% or 99%.	• This is discussed in section 6.2.5 and 6.4.2.
	• ERM is concerned with the complexity of the proposed standard, in particular the variation of the standard between electrical sub-networks and the requirement for the Panel to publish a new standard for new electrical sub-networks created through AEMO's processes.	• The Panel has attempted to reduce the complexity of the Standard where appropriate. The determination of the standard is discussed in section 6.2.
	• ERM support the Panels additional requirement for an SRAS service north of Sydney and feel that additional benefit would be realised by the definition of two electrical sub-networks within NSW to ensure a balance of load restoration capability across the state. ERM believes that other electrical sub-networks would benefit from a similar locational SRAS determination.	• Noted.
	• ERM note that the VCR values used in the assessment of the economic value of SRAS decrease over time and	• VCR is discussed in section 5.2.3 and further in section 5.4.

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	believe that this data is counter intuitive and may not account for the real costs of a longer and widespread power outage. ERM believe the Panel should reconsider the use of a VCR that decreases over time.	
Hydro Tasmania	• Hydro Tasmania request that the new standard become effective immediately after it is finalised to mitigate system restart risk in Tasmania.	• The Panel does not agree. Section 6.9 discusses the arrangements for implantation of the Standard.
	• Hydro Tasmania support the draft standards linkage between aggregate reliability and diversity	• Noted.
	• Hydro Tasmania support the Panels removal of the 1000MW minimum load and generation requirement for the determination of electrical sub-networks, and the inclusion of the requirement that a sub-network be a "viable island".	• Noted.
Major Energy Users (MEU)	• The MEU is concerned that the Panel adequately consider the impact of any actual or potential reduction in synchronous generation on the probability of a black system event, the ability to restore the power system and the degree of competition in the market for SRAS.	• This is discussed in section 7.7.
	• The MEU feels that exclusion of interconnectors in the assessment is excessively conservative; noting that the SA black system on 28 Sept. 2016 was restored via the energisation of the Heywood Interconnector.	• The Panels consideration of the availability of interconnectors is discussed in to sections 6.2.2 and 6.5.
	• The MEU feel that the	• The Panels consideration

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	reliability of any interconnector should be factored into any assessment of the aggregate reliability for an electrical sub-network.	of the availability of interconnectors is discussed in to sections 6.2.2 and 6.5.
	• The MEU considers that the review should incorporate learning's from the SA black system event on 28 Sept 2016.	• In determining the Standard, the Panel has considered the initial learning's from the SA black system event, discussed in section 2.1.4.
South Australian Office of the Technical Regulator (OTR)	• The OTR request that the probability of outage for SA include the event on 28 September 2016.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment.
	• The OTR suggest that a verification or audit and compliance system be considered to determine if SRAS procurement is sufficient, (with reference to current SA SRAS procurement).	• Enforcement of the Standard is discussed in section 7.5.
Origin Energy	• Origin observe that a black system restoration process can be expected to include periods of reduction in generation rather than a progressive increase in generation levels.	• Noted.
	• Origin believe that the modelling assumptions used in the assessment of the economic value of SRAS should be reconsidered in light of the recent SA black system event and whether an increased economic value should be place on SRAS redundancy.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment. • Refer to section 4.3 for a summary of the peer review of the NSW restoration curves.
	• Origin is supportive of the revised diversity guidelines proposed in the draft standard.	• Noted.
	• In light of the recent black system event in South Australia, where the	• Noted. The Panel's consideration of the availability of

Stakeholder	Issue/Comment	Reliability Panel Response
	restoration was enabled via the Heywood interconnector, Origin support the exclusion of interconnectors in the standard and the analysis of SRAS, as a plan for a worst case scenario.	interconnectors is discussed in to section 6.2.2 & 6.5.
	• Origin cautions the assumption that historical SRAS tenders represent a complete set of possible restart services. Origin suggests that AEMO develop a survey to generators to identify potential new providers of SRAS.	• Noted.
	• Origin is supportive of the additional requirement for SRAS in NSW	• Noted.
	• Origin is supportive of the application of different standards settings to different electrical sub-networks to reflect their unique local characteristics.	• Noted.
Russ Skelton & Associates (RSA)	• RSA believe that the AEMO restoration curves are optimistic when compared with the restoration capability following a real black system event. They provide a comparison with alternative restoration curves for the NSW1 & the NSW1+NSW2+NSW3+NSW4 scenarios.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment. • Refer to section 4.3 for a summary of the peer review of the NSW restoration curves.
	• RSA are concerned that the method for determining the probability of outage does not make adequate allowance for the change in the risk profile for SA after the closure of the Northern Power Station.	• The Panel consulted with JSSC's on the estimated probability of outage for each electrical sub-network, this is discussed in section 5.2.3.
	• RSA indicate that it is not clear from the Draft Determination or the economic analysis	• The treatment of sensitive loads is discussed in section 6.3.5.

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	undertaken by Deloitte how the impact of a black system on sensitive loads such as aluminium smelters was taken into account. Given the large loss of economic value that would occur if a smelter were shut down as a result of a black system, some further explanation of how this was taken into account in the analysis would be warranted.	

	• RSA recognise the probabilistic analysis performed around the VCR, SRAS reliability & outage probability variables. They recommend that additional uncertainty be considered related to:
	  • SRAS generator restart/operation;
	  • transmission network operation and availability; and
	  • the aggregate uncertainty of a multiple step restoration process.
		• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment.

	• In terms of uncertainty related to the restoration process, the Deloitte analysis seems to only consider the probability of the SRAS starting, not the contingent probability of successfully restarting main generating units, network elements and restoring load.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment
	• RSA are of the view that increasing the number of SRAS sources would improve the restoration time and the reliability of achieving this time and that this is not adequately accounted for in the economic assessment of SRAS.	• Noted.

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	• RSA believe that the assumption of load restoration following generation with a 90 minute delay does not account for the uncertainty in achieving load restoration.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment.
	• RSA believe that delays and failures of generation and load restoration after the completion of the stage 1 restoration should not be ignored, stating that an increased number of geographically diverse SRAS sources, energising an increased number of generators would both reduce the expected time of restoration and improve the certainty of achieving this.	• Refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment.
	• RSA accept the need for the "default blackout" as a "reasonable worst case" in the assessment and request that additional analysis be conducted to determine if an increase in the default blackout, such as a doubling, would alter the result of the analysis.	• This scenario was not investigated, however refer to section 5.4 for a summary of the additional sensitivity analysis undertaken to supplement the economic assessment.
	• RSA believes that the comparison of "marginal benefit of SRAS" with "average cost of SRAS" is not appropriate. RSA recognise the difficulty the Panel has in maintaining confidentiality of actual SRAS pricing information, however they request that an alternative way of demonstrating the economic trade-off be found.	• As described in section 5.3, the results of the economic assessment are based on actual SRAS prices, however due to confidentiality reasons the actual price data cannot be published. The average costs are shown as an indication of SRAS cost.
	• The actual power system restoration from the recent black system event in South Australia was significantly delayed from that estimated by the AEMO modelling used in	• TBC*The default blackout that was assumed by the Panel for the case where no SRAS operates was more conservative than the actual outcome for the South Australian

Stakeholder	Issue/Comment	Reliability Panel Response
	the draft determination.	restoration on 28 September 2016.
	• RSA accept that the Standard is an SRAS procurement standard, however they request that (based on advice from AEMO & TNSP's) the Panel clearly articulate the expected restoration times for key load areas, such as sensitive loads and CBD's.	• This is outside of the scope of the Final Standard. The Panel recommends in section 7.2 and 7.3 that more detailed load restoration plans be developed and communicated to the Jurisdictions.
	• Due to transmission and generation performance shortfalls the system restart from the recent South Australian black system was entirely dependent on the availability of the Heywood interconnector. It is sobering to contemplate what outcomes would have occurred if the Heywood interconnector had been damaged as a result of the severe weather.	• Noted.
	• RSA believes that the Panel should conduct discussions with TNSP's to get assurance that they are satisfied with the SRAS procurement process undertaken by AEMO.	• This is discussed in section 7.1.
	• RSA agree that enforcement of the Standard is a matter for the AER, however due to the lack of transparency in relation to AEMO activities, it is difficult for interested stakeholders to form a considered view as to whether there is an issue that would warrant investigation by the AER.	• Noted.
	• The experience of the recent black system event in South Australia demonstrates that AEMO is not able to rely on	• Noted.

Stakeholder	Issue/Comment	Reliability Panel Response
	restart services from non-contracted generators.	
	• RSA are concerned that the time and level set-points in the draft standard represent a relative reduction in the level of the standard and that this cause increased concern to market participants who are already concerned about the adequacy of the standard. As an example RSA show that an equivalent standard to the present in NSW would be set at 44% of average operational demand in 3hrs rather than 20%.	• This is discussed in chapter 6.
	• RSA believe that the aggregate reliability level of 90% is too low and recommend that a more acceptable aggregate reliability level would be greater than 96%, based on two SRAS sources, each with 80% individual reliability	• The aggregate reliability is discussed in chapter 6.
	• The experience of the recent black system event in South Australia demonstrates that actual SRAS reliability may be lower than that estimated in the economic assessment.	• Note. The Panel has included transmission reliability in the definition of aggregate reliability.
	• RSA is supportive of the variation of the standard by electrical sub-network and the additional requirement for NSW, however they query whether the definition of a northern NSW electrical sub-network would be a better solution to addressing the economics of black system restoration in NSW.	• The Rules require AEMO to determine the electrical sub-network boundaries.
	• RSA find it difficult to understand the basis for	• The Final Standard

Stakeholder	Issue/Comment	Reliability Panel Response
	the assumption of no impact on the restoration from transmission network damage, highlighting the recent experience in South Australia on 28 September 2016 as a case in point.	includes requirements to: • consider transmission reliability when calculating aggregate reliability; and • network outages for electrical diversity.
	• RSA are troubled by the way that the VCR values used as an input for the economic assessment decrease over the analysis time window. It is expected that the incremental outage costs may increase over time, or at least stay constant.	• This is addressed in section 5.4.
Snowy Hydro	• Snowy considers that the time estimate of 30mins for re-energisation from the southern SRAS to the Murray Switch-station is optimistic and doesn't adequately account for confusion, stabilising load at Mt. Beauty and mitigating high inrush currents associated with re-energising the Dederang 330/220kV transformers. Snowy estimates this step of the energisation process may take at least 90mins.	• Noted. This was considered by Mal Park.
	• Snowy believe that some of the NSW restoration curves overstate the transmission capability of the network north of the snowy region (Canberra/Yass) with reference to the 1700 MW limit on these lines, cited by TransGrid in their presentation to the public forum on 27April 2016.	• Noted.
	• With reference to clause 3.11.7(b) Snowy highlight the divergence between the AEMO and TransGrid restoration modelling results for NSW and the	• Noted. This is discussed further in section 7.1.

Stakeholder	Issue/Comment	Reliability Panel Response
	requirement for AEMO to consult with NSP's to resolve specific SRAS performance concerns.	
	• Snowy Hydro are not satisfied with AEMO's role as the sole provider of critical technical advice (restoration curves and SRAS reliability data) for the assessment of SRAS. Snowy's view is that these key inputs should be provided by an independent expert and/or TNSPs for each electrical sub-network.	• This is discussed in section 4.3.
	• Snowy considers that the sub-network specific values for G_{min} and T_{min} are based on what restart sources are currently available, and therefore the analysis doesn't account for the potential of new restart source becoming available with faster restart capability.	• The value of Gmin depends on the characteristics of the network and fleet of generation. The value of T_{min} does depend on the current SRAS offered to AEMO, but this does not prevent AEMO from procuring a faster service.
	• Snowy are concerned that the standard time and level set-points in the draft standard are less stringent than the existing time and level. Snowy show that for NSW an equivalent set-point would be 3800MW in 3 hours as a relative percentage compared to the proposed 1800MW in 3 hours.	• This is discussed in chapter 6.
	• Snowy is concerned by setting the standard as a percentage of average operational demand as opposed to peak demand.	• The Panel has changed the specification of the level to be in MW.
	• With reference to the South Australian black system event on 28 September, and published generation restoration data, Snowy show that in this real event it took 24hrs for the generation level to reach the current standard	• This level of generation was not required to meet the load due to imports on the Heywood and Murraylink interconnectors. Supply was returned to the majority of the load within this time, other than loads

Stakeholder	Issue/Comment	Reliability Panel Response
	level of 40%of peak demand in 4hrs.	affected by network damage.
	• Snowy state that the additional requirement for SRAS north of Sydney show that "it is clear that NSW should be two electrical sub-networks instead of being one".	• The Rules require AEMO to determine the electrical sub-network boundaries.
	• Snowy considers that the assumption of 100% transmission network availability is overly optimistic.	• This is considered in sections 6.3 and 6.8.
TransGrid	• TransGrid support the review of the current standard for substation batteries proposed in section 7.1 and would be happy to assist the Panel in developing such a standard.	• Noted. This is discussed in section 7.8.
	• TransGrid supports the further consideration of a reliable emergency communications network to enable a black system restoration. TransGrid propose that the Panel produce a standard for and emergency communications system that is able to function independantly from network and grid supplies.	• Noted. This is discussed in section 7.9.
	• TransGrid observe an environment of increasing system risk as a result of: (i) increasing automation of system control schemes resulting in power systems operating closer to the edge of their operating envelope (ii) An increasing amount of asynchronous generation; and (iii) anticipation of increase frequency of severe weather events TransGrid proposes that	• Noted. The Panel considers reliability and security of the NEM in its Annual Market Performance Review.

Stakeholder	Issue/Comment	Reliability Panel Response
	the Reliability Panel continually review "system risk" and report on the current risk level and anticipated future trend.	
	• TransGrid believes that a Restart Standard that doesn't mention load is inappropriate. TransGrid proposes that AEMO work with TNSP's, DNSP's and generators to establish realistic load restoration standards for different restart scenarios. These timeframes to be advised to the reliability Panel, who will determine whether they are acceptable. This information will form the basis of an "agreed" version for promulgation to JSSC's and jurisdictional Energy Ministers including advice on the expected time to restore sensitive and critical loads.	• The Rules specify that the Standard is in terms of supply, rather than load. Restoration of the load is discussed further in sections 7.2 and 7.3.
	• TransGrid considers that there should be a minimum number of restart services for each electrical sub-network and suggest that this minimum should be one more services than required (n-1)	• This is discussed in section 6.4.
	• The term "aggregate reliability" requires a more detailed definition and description to avoid confusion and mis-interpretation. TransGrid suggest "the reliability of ability of any individual SRAS will incorporate the expected start-up performance and availability of that service and any other service dependant on this restart source e.g. a large coal fired generator."	• The definition has been refined for the Final Standard.
	• TransGrid believes that New South Wales would	• The Rules require AEMO to determine the electrical

Stakeholder	Issue/Comment	Reliability Panel Response
	be best served by two electrical sub-networks and look forward to participating in a future AEMO consultation process to determine the number and boundaries of electrical sub-networks.	sub-network boundaries.
	• TransGrid states that there is no sound basis for assuming 100% transmission network availability and that when a certain level of transmission damage is incorporated in restart planning, the value of a restart source is linked with the number of transmission corridors joining that service with the rest of the network and this value should be incorporated into SRAS procurement.	• This is considered in sections 6.3 and 6.8.

	• TransGrid is concerned about the derivation and application of VCR for determining the value of SRAS. TransGrid believes that the VCR for a system wide blackout is likely to be significantly different to that currently published by AEMO. Noting that:
	  • The assessment is complex and difficult to understand;
	  • The VCR values for direct connect industrial customers used don't appear to reflect the expected impact of a prolonged outage with loss of supply to a sensitive aluminium smelter lasting longer than 3 hours.
	TransGrid proposes that the Reliability Panel conduct regular reviews of VCR for each electrical sub-network to ensure that any changes to economic circumstances are
		• The selection of the most appropriate VCR value depends on the specific purpose it is to be used for. The Panel considered the most appropriate value of VCR for the purposes of this review.
		• If the Panel requires a value of VCR in the future it will review the information available at that time to determine the most appropriate value for that specific purpose.
		• The most recently published value of VCR for the whole NEM was prepared and published by AEMO in 2014. This review of VCR was requested by the Standing Council on Energy and Resources, now the Council of Australian Government (COAG) Energy Council.

Stakeholder	Issue/Comment	Reliability Panel Response
	adequately reflected.	

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.[214] 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.

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:

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214 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.

- 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 Major supply disruptions - governance arrangements

This appendix describes the governance framework for managing a major supply disruption under the Rules, including statutory roles and responsibilities of the Reliability Panel, AEMO, Network Service Providers and Generators. It outlines responsibilities in regards to both preparing for and responding to major supply disruptions.

E.1 Roles and Responsibilities in 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.

The Reliability Panel

The Panel is responsible for reviewing and determining the Standard in accordance with the SRAS Objective (see chapter 3).[215] Other requirements under the Rules relating to the Standard are provided in Appendix D.

AEMO

Procure SRAS and oversee capability

AEMO's responsibilities under the Rules include procuring SRAS to meet the Standard at the lowest cost.[216] AEMO is to assess 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.[217]

SRAS Guideline

AEMO is responsible for developing the *SRAS Guideline* which 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;

215 Clause 8.8.3(aa) of the Rules.

216 Clause 3.11.7(a1) of the Rules

217 Clause 3.11.7(b) of the Rules

- 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.[218]

The System Restart Plan

AEMO must develop a confidential system restart plan that is consistent with the Standard to manage and coordinate system restoration activities during any major supply disruption.[219]

Recovers SRAS costs

AEMO facilitates the recovery of the cost of SRAS from those regions that benefit from the SRAS service. These costs are split equally between Generators and Market Customers.[220]

Local black system procedures

AEMO is required to prepare guidelines for usage by networks and generators to develop their local black system procedures. The networks and generators must submit the local black system procedures to AEMO for approval.

Reporting

AEMO is required to report annually on the total annual cost of SRAS in each sub-network and region, and whether SRAS was procured to a level satisfactory to meet the Standard in any sub-network.

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 local black system procedures to AEMO on the actions that would be taken in the eventuality of a major supply disruption.[221]

Generators may offer SRAS and if so, must provide all data, models and parameters that allow AEMO to effectively evaluate SRAS sources. Those contracted to AEMO to provide SRAS must monitor and maintain restart capacity and undertake annual testing in accordance with the SRAS Guideline.

Network Service Providers

The networks are responsible for providing AEMO with information to facilitate the procurement of SRAS.[222] They must provide information that AEMO reasonably requires to assess the capability of a SRAS to meet the Standard.

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218 Clause 3.11.7(c) of the Rules

219 Clause 4.8.12(c) of the Rules

220 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.

221 Clause 4.8.12(d) of the Rules.

The networks must prepare and submit local black system procedures to AEMO on the actions that would be taken in the eventuality of a major supply disruption.[223] 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.[224]

E.2 Roles and responsibilities during a major supply disruption

The Rules prescribe roles and responsibilities for various parties during the restoration of the power system following a black system condition. These parties include AEMO, TNSPs, Generators and the Jurisdictional System Security Coordinators (JSSCs).[225]

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.

AEMO will then coordinate the restart and restoration 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. AEMO also coordinates the switching on of small blocks of load to stabilise the system frequency and the voltage profile of the operating network.

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.

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222 Clause 3.11.9(I) of the Rules.

223 Clause 4.8.12(d) of the Rules.

224 Clause 4.8.12(d) of the Rules.

225 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.

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 and notify AEMO. The generator will need to stabilise the operation of any of its generating units, to the extent possible.

A generator that is contract to AEMO to provide SRAS would notify AEMO of its operational status, prepare its SRAS facilities for restart and respond to AEMO instructions.

All generators would also need to prepare their units for restart and restoration and be ready to respond to AEMO instructions and directions.

Transmission Network Service Providers (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. This includes disconnecting and isolating all network elements. The re-energisation of any network elements will need to be authorised by AEMO to reduce a collapse of the power system being restored.[226] The TNSP will also need to monitor its network to ensure that the voltage profile across its network is kept within appropriate limits and commence damage repair.

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 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.

Distribution Network Service Providers (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. This includes disconnecting and isolating all network elements. The re-energisation of any load will need to be coordinated with the TNSP and be authorised by AEMO to reduce the possibility of 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

226 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."

sub-transmission parts of its network, and start repairing the damaged elements of its network.

Jurisdictional System Security Coordinators

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

F Past Reviews and Rule Changes

Overview

Previous reviews to the Standard and related processes are as follows:

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

2012: The Panel reviewed the Interim Standard as required under the Rules, and created the current Standard with only a minor change to Interim Standard to improve clarity.

2013: AEMO reviewed the SRAS guidelines and made a number of amendments, such as revising the sub-network boundaries and clarifying SRAS applicability and reliability.

2015: AEMC's SRAS rule change modified the SRAS governance, procurement and cost recovery frameworks.[227]

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.[228] 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

AEMO reviewed the SRAS Guidelines.[229] 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;

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

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

- 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.

G Glossary

aggregate reliability	The combined probability that the contracted restart services would be expected to deliver sufficient generation and transmission capability in a sub-network to the specified level within the specified time in accordance with the System Restart Standard. This is the aggregate of the reliabilities for each of the procured SRAS in an electrical sub-network.
available generation capacity	The generation capacity that could be called on to supply load at a given time during the restoration of the power system, taking into account the limitations of generators, in terms or response times and ramp rates, along with AEMO's assessment of the capability of the transmission network to be progressively energised as part of the restoration process.
availability of SRAS	The availability of a SRAS is based on the percentage of dispatch intervals that any of the generating units essential for provision of black start capability were available in the previous year.
black system	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.[230]
Composite reliability	The reliability of a restart service as used in the Deloitte report, Economic Assessment of SRAS and subsequent Additional Sensitivity Analysis. In the Economic Assessment composite reliability of a restart service includes the combination of start-up performance and availability. In the Additional Sensitivity Analysis transmission reliability was considered in addition to start-up performance and availability.
G_{min}	The minimum required online and available generation capacity to support the ongoing restoration of the power system
major supply disruption	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. [231]
restart service	A service procured under contract by AEMO towards meeting SRS, which may involve the operation of one or more SRAS units.[232]
system restart ancillary service or SRAS	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.[233]

230 As defined in chapter 10 of the National Electricity Rules

231 As defined in chapter 10 of the National Electricity Rules

232 Note that the Deloitte reports use the terms "SRAS source" and "SRAS plant" to describe a restarts service as defined in this determination.

SRAS Contract	A contract between AEMO and a SRAS provider, which may contain the terms relating to procurement of one or more restart services.
SRAS reliability	The reliability of a specific restart service incorporating the availability of that service, the expected start-up performance and the reliability of the transmission components between the SRAS source and the first transmission substation to which it is connected. The SRAS reliability is determined by AEMO for each restart service.
SRAS Unit	Individual generating units that form part of a restart service.
Start-up performance	The start-up performance is a measure of the reliability of a restart service being able to successfully energise and deliver restoration energy when called on. Start-up performance is a component of SRAS reliability and is determined by AEMO for each restart service.
Restoration curves	The restoration curves display the AEMO's advice for the maximum amount of available generation capacity that could be called on to supply load at a given time during the restoration of the power system for a range of possible SRAS procurement scenarios.
T_{min}	The minimum reasonably achievable restoration time for restoring the available generation to G_{min} in each sub-network;
T_{max}	The maximum restoration time describes the longest period before which the system must be restarted to avoid a very prolonged restoration.

233 As defined in chapter 10 of the National Electricity Rules