SYSTEM RESTART: RESTORATION CURVES & GENERATOR RELIABILITY

INFORMATION SOURCES AND METHODOLOGY

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document at the request of the Australian Energy Market Commission, in its capacity as secretariat for the Reliability Panel, to provide information about key information sources for system restart, the methodology behind restoration curves, and the development of the reliability calculations, as at the date of publication.

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1. INTRODUCTION

The objective of this document is to provide information on AEMO's methodology in building restoration curves for each National Electricity Market (NEM) electrical sub-network in the event of a system black, as well as determining the reliability of each black-start capable generator.

This document is divided into three sections:

1. An overview of the key information sources that are used to determine restoration curves and understand generator reliability.
2. An overview of the methodology behind building restoration curves for each region.
3. An overview of the methodology behind determining generator reliability, including key factors considered.

It is important to note that the information in this document reflects the way in which AEMO has built restoration curves and determined reliability for the current SRAS contract period.

2. KEY INFORMATION FOR SYSTEM RESTART

The system restart restoration curves and reliability calculations are currently determined using information from the sources described in this section. All information is confidential to AEMO, the respective Generators and Network Service Providers.

2.1 System Restart Plans

Schedule 4.8.12 of the National Electricity Rules requires AEMO to develop a System Restart Plan for each region in the NEM. Each plan provides an overview of the process that AEMO may use to restore supply following a major system disruption, by highlighting the key transmission network corridors and sequence of generation and transmission network switching.

2.2 Tendered responses, System Restart Ancillary Services

As part of the tender process for System Restart Ancillary Services (SRAS), prospective black start generators are required to provide a range of details on their capabilities, including:

- Time to be ready to commence sending out electricity to the designated delivery point.
- Time to reach electricity export capability.
- Export capability at the delivery point (this may be lower than the rated export capability of the plant).
- Ramp rates.
- Minimum load for stable operation of the generating plant.
- The largest transformer that the SRAS equipment can energise.

A full SRAS tender process was last conducted in 2015. AEMO published a report on the completion of that process, indicating the number of services offered and accepted.[1]

2.3 Local Black System Procedures

As part of the registration process, each generator in the NEM is required to complete a Local Black System Procedure (LBSP) in accordance with guidelines issued by AEMO. The LBSP should be reviewed and updated by the respective participant after any significant change in circumstances, such as a material upgrade to the plant and its control and protection systems.

A generator's LBSP provides key information on how the generating system would respond in the event of a black system, and includes the following details that were specifically used to understand critical timings for the development of restoration curves:

- Whether the power station is staffed at all times, and if not, how long it takes to arrive at site.
- Whether an external supply of electricity is required to safely shut down the units before restart.
- What (if any) emergency backup systems are installed to safely shut down units.
- The time required to safely shut down units and prepare for restart.
- The number of units that are capable of tripping to house load.
- The length of time that the generating unit can be without external supply and still have the capacity to restart once an external supply is available.
- What fuel arrangement is present, and the length of time the unit can run without resupply.
- The ramp rates for bringing the unit back online.

[1] *SRAS Tender Process Report*, 2 July 2015. Available at: http://aemo.com.au/-/media/Files/PDF/SRAS-completion-report.ashx.

2.4 Registered Generator Performance Standards

Where information is missing or outdated in the LBSP, some information, such as the registered capacity and number of units, is taken from the generator performance standards (GPS). This is typically only required for smaller and older generators.

2.5 AEMO'S detailed power system modelling and simulation

During the 2015 tendering process, AEMO conducted extensive modelling of proposed system restart paths using an electromagnetic transient simulation software, PSCAD™/EMTDC™[2]. This process highlighted critical limitations in particular regions, such as the need to bring sufficient units online before attempting to energise certain large transformers. These limitations were included in the development of restoration curves.

[2] *Power System Modelling and Study Methodology for SRAS Generator Evaluation*, September 2015. Available at: https://www.aemo.com.au/media/Power%20system%20modelling%20and%20study%20methodology%20for%20SRAS%20generator%20evaluationFINAL.pdf

3. OVERVIEW OF THE RESTORATION CURVES

The system restart restoration curves are a simplified visual representation of the critical path times for different black start capable generators. The curves are developed for each electrical sub-network determined by AEMO for SRAS purposes (Queensland North, Queensland South, New South Wales (including the Australian Capital Territory), Victoria, South Australia, and Tasmania). This chapter explains the methodology behind building the restoration curves in detail.

3.1 Determining restoration curve parameters

Using the information detailed in Chapter 2, a summary of key parameters is built for each major power station in the specified region. These include:

1. Power station name and owner.
2. Fuel source.
3. Maximum power (accounting for auxiliaries, and less than or equal to the maximum registered capacity).
4. Minimum power (if applicable).
5. Drive time to site.
6. Time to export, and time to maximum.
7. Acceptable amount of time without supply.
8. Load block size.
9. Any other parameters that may affect the critical restart path of the generator.

In the instance that auxiliary load or ramp rate information is not available in the sources explained in Chapter 2, assumptions are made based on industry experience:

1. Gas: 2% auxiliary load.
2. Coal: 5 to 10% auxiliary load.
3. Hydro: 2% auxiliary load.
4. Coal ramp rate: 5% per minute.

3.2 Developing the restoration curve

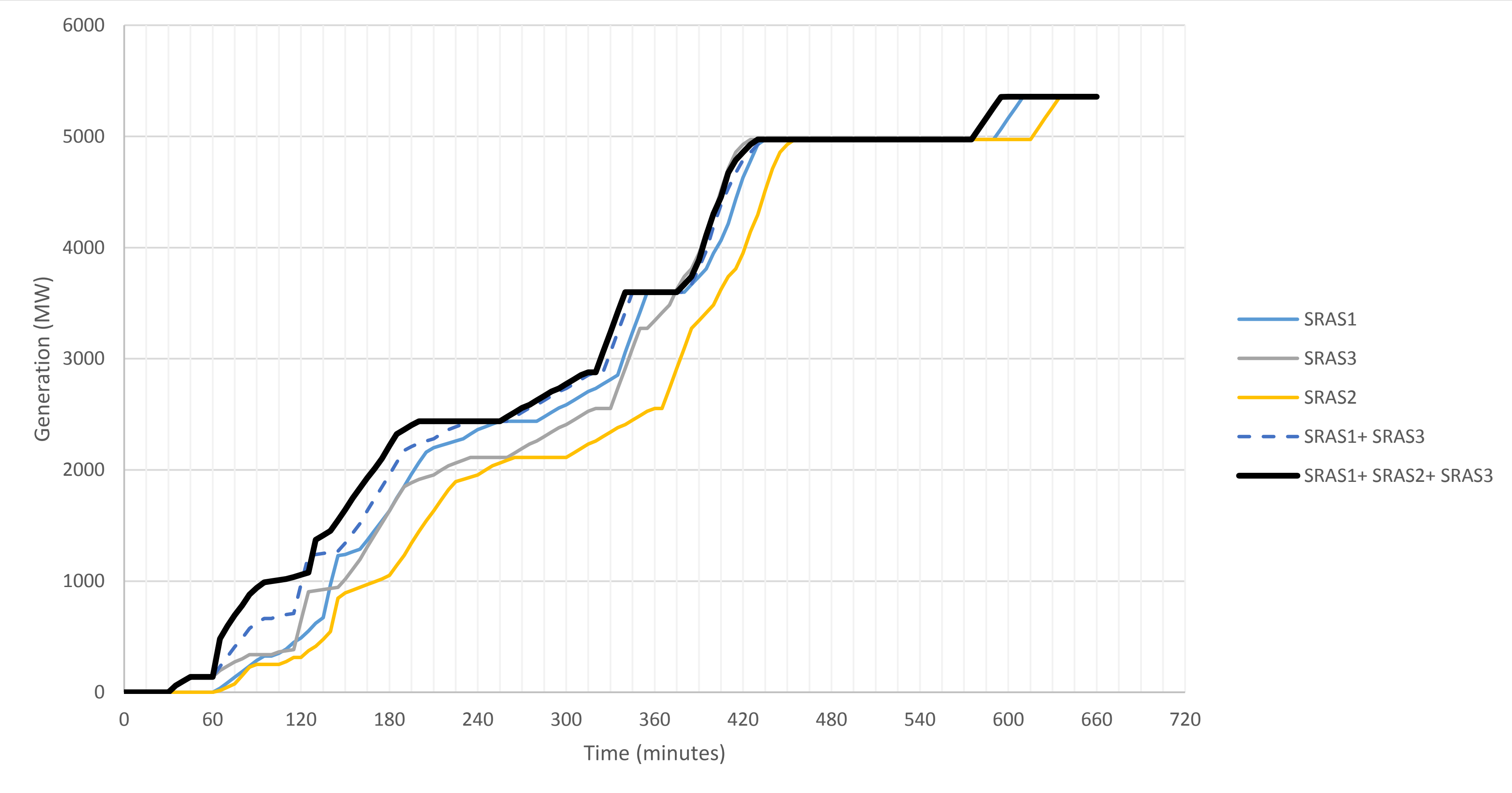
The restoration curve is the final result of calculating the export rate of the relevant black start generator, determining how quickly the surrounding area can be energised, and then calculating the export time for each generator in the region. The curve represents the sum total of the sent out capability for each available unit in the region, and is measured in megawatts (MW).

The restoration commences at 0 minutes – this is when the black system occurs. Shortly after, the selected black start generator commences their start up procedure. Once the black start generator has commenced export, the surrounding transmission network can be progressively energised, following the paths identified in AEMO's System Restart Procedure. Approximately five minutes is allowed to energise one transformer or one branch leading away from the black start generator. Once the external bus of a non-black-start generator is energised, that generator can either:

1. Begin the process of safe-shutdown and restart with the external supply; or
2. Commence synchronising and exporting generation to the grid (whatever is specified in the LBSP).

The process continues in a radial fashion until the system restart standard (40% of maximum demand within four hours) is achieved, or all generation is online.

Figure 1 Example of restoration curves for a range of black start generators in a sub-network



4. OVERVIEW OF SRAS RELIABILITY FIGURES

The SRAS reliability overview provides a comparison of each black start capable generator in the NEM. This information was provided by AEMO to the Australian Energy Market Commission (AEMC) in defining the restoration targets in each NEM electrical sub-network for the Draft System Restart Standard.

It considers five factors outlined below (points of failure, components, availability, fuel storage, and previous experience (if applicable)) and provides a final score of poor, good, very good, or excellent for each potential black start generator.

A more comprehensive process will apply for any future tenders where an Aggregate SRAS Reliability is required for each sub-network.

4.1 Points of failure

This category considers the number of available units within each potential SRAS service, and how many of them are needed for the SRAS source to energise sections of transmission network and auxiliaries of nearby large power stations. This information is taken from the tendered submission of the black start generator and detailed power system modelling carried out by AEMO for the 2015 SRAS procurement. For example:

- Black start generator A: coal-fired generator with TTHL capabilities, can meet its SRAS target with any one of four potential units.
- Black start generator B: coal-fired generator without TTHL capabilities, requires one of one units to meet its SRAS target.
- Black start generator C: Gas-fired generator comprising four units, all of which are required in order to energise auxiliaries of large power stations.

Generator A would score higher than Generator B, as the presence of multiple units provide a number of levels of redundancy, in the event that a unit was out for maintenance or failed to initiate the TTHL sequence in the black system event.

Generator A would also receive a better score than Generator C, as Generator C would require all four constituent units to be operational in order to meet SRAS requirements.

This category is the most significant factor in the reliability determination, as the technology and redundancy are fundamental to the power station design and cannot be readily modified.

4.2 Components

This category considers the age and sophistication of the generator primary components and control systems, such as excitation system and governor, and protection systems. This information is derived from each unit's GPS and the information provided by the SRAS tenderers for the 2015 SRAS procurement. This information is kept up to date with any changes or upgrades at the power station, as notified to AEMO. Units that have been more recently upgraded are likely to score more highly here, as their equipment is more recently tested by AEMO, and likely to have greater capability.

4.3 Availability

This category compares the stated availability (quoted by the black start capable generator in the tender submission) with the average real availability of the generator (the percentage of dispatch intervals that any of the generating units essential for provision of black start capability by the SRAS offer was not available). For example, if a generator stated an availability of 99% in their tendered submission but the demonstrated availability is 80% in the previous year, this would result in a low score in this category.

4.4 Fuel storage

This category considers the fuel supply to the black start capable generator, and the likelihood for that to deplete during system black event. This information is derived from the LBSP as well as inherent characteristics of the power station fuel type. For example, a coal-fired power station with a dedicated coal mine, and a hydro power station with a large dam, will receive higher scores than a gas turbine with limited storage capability, or multiple gas-fired stations all of which rely on the same gas pipeline.

4.5 Previous experience

This category considers whether the black start capable generator has held a SRAS contract in either the 2008, 2012, or 2015 contracts. A station that has been contracted for one or more periods would score more highly than one that has not previously been involved, as they would have a better understanding of the process and the testing requirements than a generator that has not been previously involved.

MEASURES AND ABBREVIATIONS

Abbreviations

Abbreviation	Expanded name
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
EMTDC	Electromagnetic Transients with DC analysis
GPS	Generator Performance Standards
LBSP	Local Black System Procedure
MW	Megawatts
NEM	National Electricity Market
PSCAD	Power System Computer Aided Design
SRAS	System Restart Ancillary Services
TNSP	Transmission Network Service Provider
TTHL	Trip To House Load