DGA Consulting

INDEPENDENT REVIEW OF SYSTEM RESTART ANCILLARY SERVICE PROCESS IMPROVEMENTS

Australian Energy Market Operator

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Note: This report is formatted for double-sided printing, so there may some 'blank' pages so that new chapters always start on the right-hand side.

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ABBREVIATIONS AND NOMENCLATURE

AC	Alternating current
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Cranking path	The specific transmission path and equipment energized by a black-start unit to start ("crank") another generating unit and may include transformers, breakers and transmission lines
DC	Direct current (as compared to AC)
Black-start unit	A generating unit, that following its disconnection from the power system, is 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.
Generating plant	In relation to a connection point, includes all equipment involved in generating electrical energy that includes one or more generating units. (Also referred to as a power station, generating station, power plant, powerhouse or generating plant).
Generating unit	The actual generator of electricity and all the related equipment essential to its functioning as a single entity.
kV	kilo Volts, a thousand volts
MW	Mega Watt, a million Watts
NEM	Australian National Electricity Market
NER	Australian National Electricity Rules
NSW	New South Wales
Power plant	See generating plant
Power station	See generating plant
Regional network	The electrical transmission network in each of the five regional networks in the NEM—Queensland, New South Wales, Victoria, South Australia, and Tasmania
SRAS	System Restart Ancillary Services—a service provided by facilities with black-start capability which allows energy to be supplied and a connection to be established, sufficient to restart large generating units following a major supply disruption.
SRS	System Restart Standard—as determined by the Reliability Panel in accordance with NER clause 8.8.3(aa), for acquiring SRAS.

State network	Regional network
Sub-network	A part of the national grid determined by the AEMO as defined in NER §3.11.4B for the purpose of acquiring SRAS
Substation	A facility where two or more lines are switched for operational purposes. May include one or more transformers so that some connected lines operate at different nominal voltages.
Transmission circuit	Transmits electrical energy between substations with conductors for only one circuit
Transmission line	Transmits electrical energy between substations on a single set of towers or pylons with conductors for one or more circuits
TTHL	Trip-to-house load, the ability of a generator to remain operating after being disconnected from the network

1 EXECUTIVE SUMMARY

The Australian Energy Market Operator (AEMO) was established to manage the National Electricity Market (NEM) and gas markets. The NEM is a wholesale market for supplying electricity to retailers and end-users in Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania. The AEMO is 60% owned by government members and 40% by industry members. The AEMO operates within a broader market governance structure alongside the Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER).

Among the services that the AEMO manages is System Restart Ancillary Services (SRAS). The objective of SRAS is to minimize the expected costs of a major supply disruption to the extent appropriate. The AEMO must make reasonable efforts to acquire SRAS that meet the System Restart Standard (SRS) at the lowest cost. The SRS is determined by the Reliability Panel to meet the requirements of the Australian National Electricity Rules (NER). Specifically, the SRS identifies the maximum amount of time that SRAS are allowed to take to restore a specified supply level target.

1.1 The 2013 DNV KEMA review

In 2013 the AEMO engaged DNV KEMA to review certain aspects of the AEMO's responsibilities to procure SRAS under §3.11.4A of the NER. DNV KEMA was asked to review seven issues that they found fell into three major areas:

1. The probability of the assumed blackout condition—NEM-wide versus state-wide;
2. The number of sub-networks and SRASs in each regional network; and
3. The SRAS definition, quantity and assessment.

Among other things, the DNV KEMA review recommended that the AEMO consider implementing measures to ensure that submissions can meet the standard's restoration targets. And, that this should be done through detailed simulation of each step in energizing cranking paths to demonstrate technically feasibility. This should include steady-state, dynamic and electromagnetic transient modeling and analysis.

In the past the AEMO has only performed steady-state (powerflow) modeling of SRAS submissions using a DC powerflow model. Such DC powerflow modeling can identify potential steady-state overloads but cannot identify voltage issues in an SRAS/cranking path, or the many other types of technical issues can occur in dynamic and/or transient conditions. Industry best practice is to also perform dynamic/transient modeling when evaluating black-start plans.

DNV KEMA pointed out that relying on powerflow simulation alone is not adequate to identify the many types of technical concerns that can occur during black start/restoration activities. Thus, DNV KEMA recommended that the AEMO perform dynamic/transient modeling when evaluating SRAS submissions. Relying on powerflow modeling alone does not confirm that a proposed SRAS submission can fulfill the standard's restart requirements. It could result in payments to SRAS providers for services they can't actually deliver following a blackout.

DNV KEMA recommended that the AEMO investigate the available sources for such modeling data and consider options for performing such modeling in future SRAS submissions including:

- Obtaining such data and performing the associated dynamic/transient modeling;
- Delegating to or contracting with the applicable network service providers to perform such analysis; and
- Retaining the services of a qualified consultant to perform such modeling for the AEMO.

1.2 AEMO responses to the 2013 DNV KEMA review

Following release of the DNV KEMA review, the AEMO began to implement most of their recommendations. In particular, the AEMO implemented the recommendations regarding cranking-path modeling of future SRAS Submissions. The AEMO:

- Contracted a qualified international consultant to assist in developing the necessary analytical tools to perform the recommended studies;
- Developed the necessary database of the transmission and generation system components required to study the 2015 SRAS submissions;
- Developed a sound plan to use the tools and database to evaluate the SRAS submissions; and
- Implemented the plan to evaluate the 2015 SRAS submissions.

1.3 DGA review

The DGA team has reviewed the models, methods, procedures, and results of the 2015 SRAS review process and reached the following conclusions:

1.3.1 Conclusions—SRAS procurement guidelines

The AEMO developed SRAS *Guidelines* to comply with the requirements of the SRS.[1] The *Guidelines* set out the process by which AEMO will assess any offered or contracted SRAS. While the *Guidelines* cover all aspects of the process, this review focuses on the simulation requirements.

The simulation requirements are listed in Table A3 in Appendix A of the *Guidelines*. The table list details regarding 18 specific and detailed requirements. The 2015 method clearly demonstrates that they have been met.

1.3.2 Conclusions—sub-networks

The 2015 method allows a technically sound analysis to be made that can determine the efficacy of the SRAS units regardless of sub-network boundaries. The 2015 study indicated a need for two sub-networks only in Queensland. This is consistent with the DNV KEMA review and is reasonable.

1.3.3 Conclusions—modeling

The 2015 SRAS model developed by AEMO staff is of equal quality to those used by the best ISOs. The AEMO approach developed an extensive database of necessary system technical characteristics for generators, transmission and various protection elements. This database used state-of-the-art methods to produce a thorough model of the system.

AEMO staff developed a comprehensive modeling tool capable of properly modeling the various requirements and system responses necessary to evaluate black-start submissions for SRAS.

1.3.4 Conclusions—study method

The 2015 process is a major improvement from the previous method. The previous method relied on inadequate technical analyses, engineering judgment, and rules of thumb. The 2015 process uses industry-standard analysis tools and techniques to make the SRAS

1. AEMO, SRAS Assessment Guidelines, Version 2, 15 December 2011.

selections. The previous method effectively accepted 'extra' SRAS submissions to assure complying with SRS resulting in much higher costs for SRAS services.

The study method includes these features:

- It is logical—the steps taken to develop the database and tools follow a logical pattern consistent with the goal of evaluating SRAS submissions;
- It is transparent—while there are a number of complex technical calculations involved, there are no hidden steps or procedures;
- It is consistent—it will yield the same results when used repeatedly and by other parties; and
- It is technically sound—it uses the best available approach for data, and the analysis tools are modern and consistent with the best international practice.

1.3.5 Conclusions—results

The final results are reasonably similar to those estimated in the earlier DNV KEMA review—the DNV KEMA review suggested 6 sub-networks and 12 submissions, while the 2015 method found 6 sub-networks and 10 submissions were necessary to meet the SRAS standard.

The results are now backed by sound data and methodology, as discussed above. The previous method—as noted in the DNV KEMA review—was based on a greatly simplified (and inadequate) analysis.

The results demonstrate and document the ability of the selected SRAS submissions to fulfill the SRS. With the 2015 method, each proposed SRAS submission was evaluated to determine how much generation could be started to meet the SRS.

The total cost of SRAS services are reduced from $56 million/year with the previous method to slightly more than $21 million/year with the 2015 method.

These results demonstrate the AEMO's wisdom in developing the 2015 approach. The data and method are technically sound and properly applied allowing the AEMO to confidently improve the SRAS selection process; a process that resulted in a significant cost reduction.

The annual savings of nearly $30 million/year shows the value of the AEMO's investment in developing the data, techniques and tools used in the 2015 regime.

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1.4 Recommendations

We make twelve recommendations for action as discussed below. Additional information regarding these recommendations is presented in Chapter 7, beginning on page 35.

1.4.1 For action by the Reliability Panel

1. We believe the concept of sub-networks has outlived its usefulness and should be dropped; from the SRS;
2. In some cases the distance between load centers is quite long where the selected SRS may not be able to energize or restart some portion of the system even after many hours, so the SRS should require the selected SRAS have a reasonable expectation of restoring the entire region within a day or two;
3. The SRS now has a 90-minute requirement that is no longer needed with the 2015 method, so the 1.5 hours (90-minute) requirement should be dropped from the SRS;

The SRS addresses issues regarding diversity including electrical, technological, geographical, and regarding fuel sources that are outdated or unclear in light of the 2015 analytical methods;

4. Electrical diversity is based on avoiding a single point of failure even though restoring the system involves numerous single steps that violate this principle, so it should be clarified or dropped;
5. Technical diversity is based on avoiding similar technologies being procured, however, there are limited variations with each region and, if implemented, increase costs needlessly and so should be dropped;
6. Geographic diversity related to events such as natural disasters, however, with the limited number of submissions in each region it is unclear how much of a premium should be paid for such diversity, and so this should be clarified or dropped;
7. Fuel diversity is a concern only when an SRAS submission does not have local fuel storage, so SRS should be modified so that only units that have less than 12-hours local fuel storage are excluded from providing SRAS;

1.4.2 For action by the AEMO

8. The 2015 computer database and analysis method is far superior to the previous method and has resulted in technically sound results that have significantly reduced SRAS costs. They should be continued;

9. Other ISOs and transmission owner/operators have found it very useful to have black-start generators demonstrate that they can energize at least one transmission element beyond the generator's step-up transformer, so we recommend that AEMO consider requiring this in its black-start testing protocol;

10. Effective 1 July 2015 the *Rule Determination* allows the AEMO to procure SRAS outside the tender process prescribed in the NER, so the AEMO should develop a method for procuring SRAS outside the tender process;

11. Some generators have submitted SRAS offers as bundled groups of generating units, and while this is acceptable, the AEMO should require them to also offer each resource independent of the others.

1.4.3 For action by policy makers

The AEMC has made it clear that effective 1 July 2015 SRAS should be procured with the lowest possible cost, however, the AEMO is prevented from negotiating SRAS prices. While on a NEM-wide basis there is likely sufficient competition for market forces to work, SRAS is procured on a regional basis and there is no competitive market for SRAS in at least three of the five NEM regions. There is an obvious potential for abuse through monopoly rents in these regions.

Neither the AEMO, nor any other agency, now has the obvious ability to investigate or prevent such market-power abuse. Without remedy, the situation is ripe for monopolistic abuse.

12. While we believe the AEMO should maintain its independence and not become embroiled in SRAS price disputes, some remedy is called for and we recommend a process for reviewing prices that are not cost-reflective including possible binding arbitration.

2 BACKGROUND

The Australian Energy Market Operator (AEMO) was established to manage the National Electricity Market (NEM) and gas markets from 1 July 2009. The AEMO is the national energy market operator and planner. The AEMO supports the industry in delivering a more integrated, secure, and cost-effective national energy supply.

The AEMO is 60% owned by government members and 40% by industry members and operates under the governance of a Board that includes nine skills-based non-executive Directors and the Chief Executive Officer. The AEMO operates within a broader market governance structure alongside the Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER). The AEMC determines the policy environment and governance structures that shape Australia's developing energy markets and sets the operating requirements and obligations of market participants.

The NEM is a wholesale market for supplying electricity to retailers and end-users in Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania. Operations are based in five interconnected regions that largely follow state boundaries.

The NEM operates the world's longest interconnected power system—from Port Douglas in Queensland to Port Lincoln in South Australia—a distance of around 5,000 km. More than $10 billion of electricity is traded annually in the NEM to meet the demand of more than eight million end-use consumers.

The AEMO's functions are prescribed in the National Electricity Law. Procedures and processes for market operations, power system security, network connection and access, pricing for network services in the NEM and national transmission planning are all prescribed in the Australian National Electricity Rules (NER).

The AEMO's core functions include:

- Electricity Market—Power System and Market Operator;
- Gas Markets Operator;
- National Transmission Planner;
- Transmission Services; and
- Energy Market Development.

This report addresses certain aspects of the AEMO's role regarding the electric system.

2.1 SRS and SRAS

Among the services the AEMO manages is System Restart Ancillary Services (SRAS). The objective of SRAS is to provide reasonable assurance that the system can be restarted following a regional blackout. The AEMO is to procure the least-cost combination of SRAS submissions that meet the SRS. This is consistent with the national electricity objective. [2]

The SRS is determined by the Reliability Panel to meet the requirements of the NER. Specifically, the SRS identifies the maximum amount of time that SRAS are allowed to take to restore a specified supply level target. The SRS also establishes a number of other parameters, including the strategic, geographic, technology and fuel diversity of SRAS, as well as the principles that AEMO must consider when developing the boundaries of electrical sub-networks.

Some of the specific requirements of the SRS include:

- Target times for restoration:
  - Within 90 minutes— auxiliaries should be energized for power stations capable of meeting 40% of the network's annual peak demand;
  - Within four hours—generation and transmission should be restored that could supply 40% of the network's annual peak demand;
- SRAS reliability:
  - SRAS must be ≥ 90% reliable;
- Electrical sub-network boundaries should consider:
  - Number and strength of transmission corridors;
  - Electrical distance;
  - Amount of generation and load (≥ 1,000 MW).

2. NER §3.11.4A and §11.2 describe the SRAS requirements and the AEMO's role and requirements. NER §8.8 describes the role and requirements of the Reliability Panel.

2.2 2013 DNV KEMA review

In 2013 the AEMO engaged DNV KEMA to review certain aspects of the AEMO's responsibilities to procure SRAS under §3.11.4A of the NER. DNV KEMA was asked to review seven issues that they found fell into three major areas:

1. The probability of the assumed blackout condition—NEM-wide versus state-wide—DNV KEMA found that:
   - While the AEMO now assumes a NEM-wide blackout in determining SRAS requirement; there is no such requirement in the NER, or SRS;
   - The AEMO proposes to use region-wide blackouts as the basis for future SRAS requirements;
   - There is no credible event that could cause a NEM-wide blackout; and
   - There are relatively few events that could cause a region-wide blackout; and
   - They agree with the AEMO's proposed change to only consider statewide blackouts regarding SRAS.
2. The number of sub-networks and SRASs in each—DNV KEMA found that:
   - The AEMO proposed reducing the number of sub-networks from ten to seven;
   - The number of sub-networks should be reduced to six by boundary changes between New South Wales Queensland.
   - The resulting main New South Wales sub-network should have two SRAS;[3] and
   - The AEMO use transmission break points as the basis for determining sub-network boundaries in the future.
3. The SRAS definition, quantity and assessment—DNV KEMA found that:
   - With the present approach, it is possible for an SRAS to be unable to effectively meet the SRS target to serve 40% of peak load within 4 hours;

3. Referring to two NSW sub-networks is somewhat misleading since one would include only a small part of northern NSW that would be combined with southern Queensland, while nearly all the load and generation is in a single network.

- The AEMO-proposed approach would make it possible for more of the existing black-start resources in NEM to participate in the SRAS tender process, making the process more competitive;
- That the AEMO's proposed changes to SRAS tender requirements and definitions should improve the likelihood of meeting the SRS targets, especially supplying 40% of peak load within four hours; and
- A more rigorous AEMO technical assessment process for SRAS tenders would improve the likelihood of actually meeting the SRS targets should a blackout occur.

The DNV KEMA review recommended that the AEMO consider implementing these measures to ensure that the standard's restoration targets can be met by "winning" submissions:

- Confirm through detailed simulation that each step in energizing the cranking path and remote generating unit start up is technically feasible. This should include steady-state, dynamic and transient modeling and analysis.
- Agree on procedures with applicable network service provider(s) to fulfill the switching plans, procedures and timelines needed to achieve the 90-minute target.

In the past, the AEMO has relied on only steady-state (powerflow) modeling of SRAS submissions using a DC powerflow model. Such DC powerflow modeling can identify potential steady-state overloads but cannot identify voltage issues in an SRAS/cranking path analysis; nor can it identify the many other types of technical issues that can occur in dynamic and/or transient conditions. Industry best practice is to also perform dynamic/transient modeling when developing black start plans.

DNV KEMA pointed out that relying on powerflow simulation alone is not adequate to identify the following types of technical concerns that can occur during black start/restoration activities:

- Unacceptable voltage or frequency swings during generator auxiliary motor starting;
- Black start generator "pull-out" or angular instability;
- Transient/switching over voltages;
- Short-term system over-voltages or over-frequency conditions as a result of load rejection; or

- Transformer energizing/self-excitation concerns.

Thus, DNV KEMA believed that the AEMO should perform dynamic/transient modeling when evaluating SRAS submissions. Relying on powerflow modeling alone does not confirm a fully workable black-start plan. It could result in payments to SRAS providers for services they can't actually deliver following a blackout. Even worse, it could result in equipment damage or failure during actual restoration efforts, thus further complicating the overall restoration effort and incurring expensive equipment repair or replacement.

DNV KEMA recommended that the AEMO investigate the available sources for such modeling data and consider options for performing such modeling in future SRAS submissions including:

- Obtaining such data and performing the associated dynamic/transient modeling;
- Delegating to or contracting with the applicable network service providers to perform such analysis; and
- Retaining the services of a qualified consultant to perform such modeling for the AEMO.

In addition to reducing the risk of equipment damage or failure, including dynamic/ transient modeling in the SRAS submission review will help to remove inadequate performers from the list of winning submissions and provide the AEMO with vital information on cranking paths or switching steps that must be observed for successful system restoration.

2.3 AEMO actions

The AEMO made changes in response to the DNV KEMA review.

2.3.1 The number and boundaries of sub-networks

It is the AEMO that determines the number and boundaries of sub-networks consistent with the SRS. The power-system database and tools used to evaluate the 2015 SRAS submissions allowed the AEMO to determine the sub-networks in a different way from previous years. Rather than rely on deterministic criteria and engineering judgment, the AEMO used analytic tools to determine the need for sub-networks.

The DNV KEMA REVIEW suggested that sub-network boundaries should be defined by likely transmission break points in meeting two SRS guidelines—"the number and strength of transmission corridors", and "electrical distance". With the 2015 tools the AEMO was able to analytically determine when sub-networks were needed and their boundaries.

The AEMO's studies demonstrated that the NEM could meet the SRS requirements with six sub-networks—one for each regional network and two in Queensland.

2.3.2 SRAS study and modeling

As discussed above, DNV KEMA recommended that the AEMO perform dynamic/transient modeling when evaluating SRAS submissions. The AEMO fully embraced this recommendation.

Working with the network service providers and generators the AEMO developed a detailed system model and tools to study the SRAS submissions. They engaged a reputable international consultant to assist them in developing the database tools for the necessary studies. The AEMO used various industry standard tools and techniques to develop a database of the necessary technical characteristics of the existing system. The database and tools were then used to evaluate the various SRAS submissions.

The primary tool used was PSCAD.[4] PSCAD was used both to develop the model and to make the transient system analyses. AEMO staff together with their consultant developed models for the power system elements including transmission lines, transformers and other major substation components, generators, and protection equipment.[5] The models for all the major power system components above 100 kV (and for selected lower voltage facilities) were included in their database.

The database and simulation model were used to evaluate each SRAS submission. The study and results are discussed in detail in chapter 5 beginning on page 25, below.

2.4 This review

In 2013 the AEMO began a review of its responsibility regarding SRAS under clause 3.11.4A of the *National Electricity Rules*. As this review neared its completion, the AEMO sought an independent review regarding the AEMO's proposed changes in the rules and associated processes and methods.

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4. PSCAD is a simulation tool for analyzing power systems transients. It is also known as PSCAD/EMTDC. PSCAD is most suitable for simulating the time domain instantaneous responses, also popularly known as electromagnetic transients of electrical systems.

5. In some cases network service providers and generators provided data.

The AEMO engaged DGA Consulting to independently review these activities:

1. Review and comment on the AEMO's compliance with its SRAS procurement guidelines;
2. Review and comment on the assumptions, basis, methodology and quality control of AEMO's dynamic modeling of the NEM system restart response.
3. Review and comment on AEMO's application of the system restart dynamic modeling for assessing proposed services compliance against the system restart standard
4. Develop an independent view of AEMO's achievement of the National Electricity Objective in determining the SRAS solution;
5. Provide an independent view of AEMO's overall achievement of the System Restart Objective as set out in clause 3.11.4A(a) of the *National Electricity Rules*.

These items are addressed in this report.

3 THE PREVIOUS SRAS METHOD AND APPROACH

In the previous SRAS regime, as used in the 2011 SRAS procurement, the AEMO accepted service tenders for delivery of such service from trip-to-house load (TTHL) facilities, hydroelectric generating facilities, gas turbines or other types of facilities that meet the SRAS requirements. (This is also true in the 2015 method.)

In both the previous and 2015 regimes the AEMO assumes that there is no damage to generation or transmission infrastructure as a result of the blackout event. In effect, this assumes that all facilities are available for restarting each sub-network. This is a somewhat optimistic assumption since it will not be true in every case. On the other hand, AEMO conservatively assumes that:

- Each sub-network must be capable of starting from the winning SRAS submission(s) without aid from the interconnectors to neighboring networks;
- The entire regional network is de-energized (blacked out); and
- That they can energize generation equal to 40% of annual peak load.

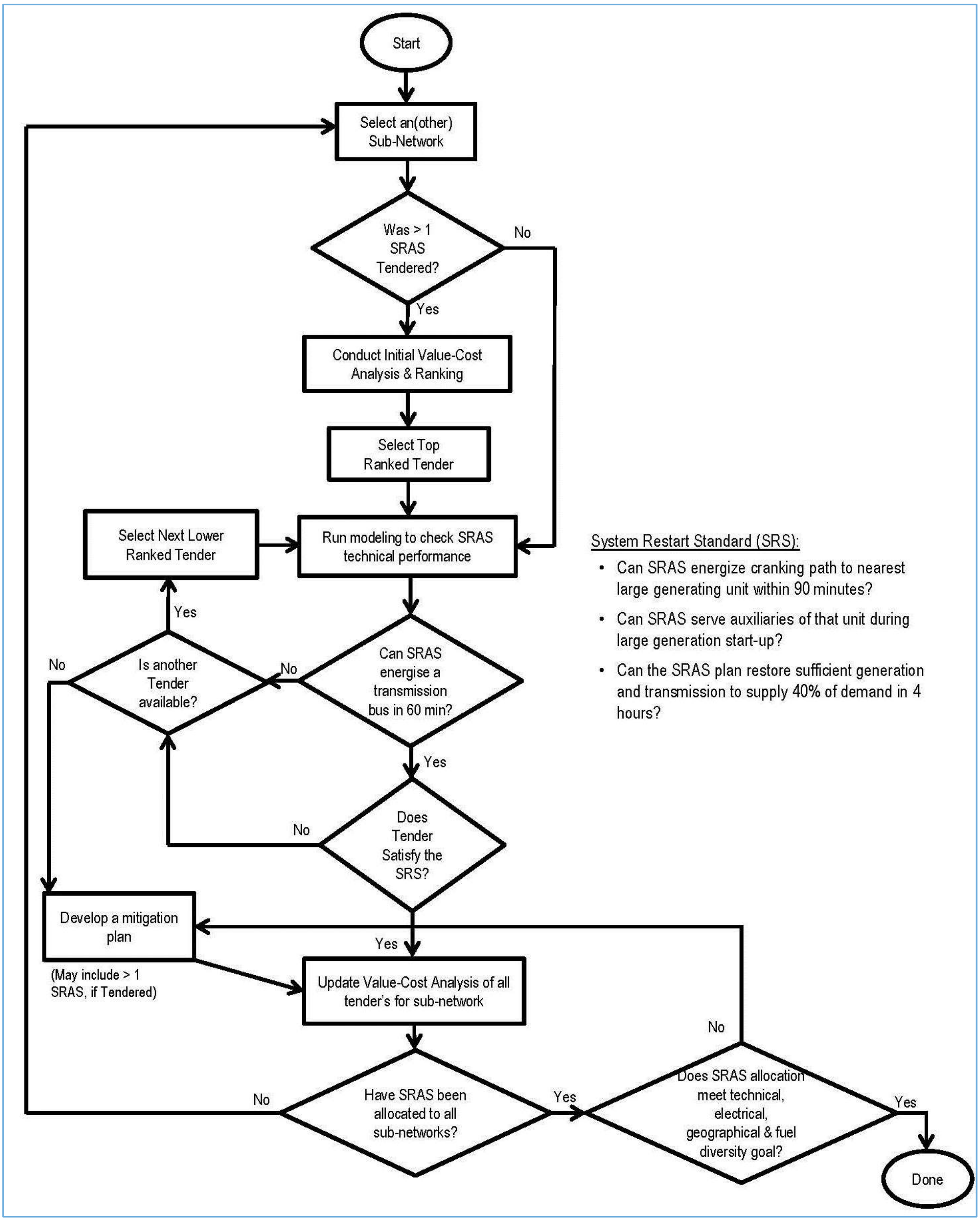
These are conservative because in almost every case both the internal SRAS unit(s) and most interconnectors will be available during the restart process, some portion of the region's network will remain in service, interconnections will be used to restore the transmission system, and the peak load only occurs once a year.

The SRS defines both *primary* and *secondary* SRAS tenders. The AEMO tries to procure primary SRAS, but will use secondary SRAS when insufficient primary SRAS tenders are available.

Under the previous regime, in order to help ensure that a primary SRAS can re-supply and energize the auxiliaries of a large generator in 90 minutes or less, the AEMO required that an SRAS tender be able to energize a large generator's auxiliaries in 60 minutes or less. This provided a 30-minute margin allowing for operational contingencies. However, under the previous regime the AEMO found some SRAS tenders could only achieve the 60-minute requirement by energizing an adjacent larger generating unit (i.e., located at the same power station as the SRAS unit). Although this technically met the wording of the 90-minute target in the standard, the AEMO reported that SRAS tenders using this approach were often unable to provide the transmission system restoration speed necessary to meet the Standard's four-hour restoration target.

The previous SRAS selection process is shown in Figure 1. This process can be compared with the 2015 process described in the next chapter.

Figure 1: Previous SRAS tender technical assessment process



4 AEMO MODELING—2015 METHOD

The AEMO procures SRAS as described under the NER §3.11.5(b)(9). Accordingly, the main principles that the AEMO applies in assessing submissions include:

- Select the SRAS service (or combination) that is the best value for each *electrical sub-network* that meets the SRS during the contract term;
- The tenderer must be a *Registered Participant* (or intends to register);
- Select the SRAS for an *electrical sub-network* consistent with the SRAS procurement objectives (§3.11.4A(c) of the NER and the SRAS Quantity Guidelines);
- The AEMO will consider:
  - The prices at which the Service is offered;
  - The extent to which the offered Service exceeds the minimum requirements;
  - The number, nature and impact of any requested changes to the proposed agreement;
  - The tenderer's financial position including its corporate credentials and financial stability;
  - General compliance with the NER; and
  - Any other factors AEMO considers to be relevant.

The technical criteria were considered to be the primary determining factor. Once a set of technically suitable options was determined, the most cost-effective solution was selected.

4.1 Data and model

The DNV KEMA review recommended that the AEMO confirm through detailed simulation that each step of energizing the cranking path plan and remote generating unit start up is technically feasible. And, that this should include steady-state, dynamic, and electromagnetic transient modeling and analysis.

In the year-and-half since the DNV KEMA review was completed, the AEMO undertook an ambitious plan to implement this recommendation. They engaged a consultant with the specialized expertise to support their data and develop the electromagnetic transient model.

The AEMO developed a dynamic model for nearly all of the NEMs' high-voltage transmission and generation system. This was a very large effort that developed a database of:

- Transmission lines—developed from conductor and tower configurations;
- Generator data either from specific data from the owners or from manufacturers;
- Relaying settings—from the transmission network system providers and generators; and
- Transformers and other major substation components.

There are only a few other network operators that have undertaken such extensive model development.

The AEMO acquired the computer tools and developed a set of system models tailored to their specific SRAS needs. The model allows the AEMO to simulate energizing the generation and transmission system in a step-by-step manner. The model allows monitoring of a long list of variables and conditions including:

- Dynamic real and reactive power flows;
- Voltage;
- Frequency;
- Harmonics;
- Transient voltages;
- Relay operations;
- Transformer in-rush currents;
- Surge-arrestor over-voltages and energy dissipation;
- Zero and negative sequence currents and voltage;
- Generator auxiliary in-rush current and voltage, and load rejection; and
- Many others.

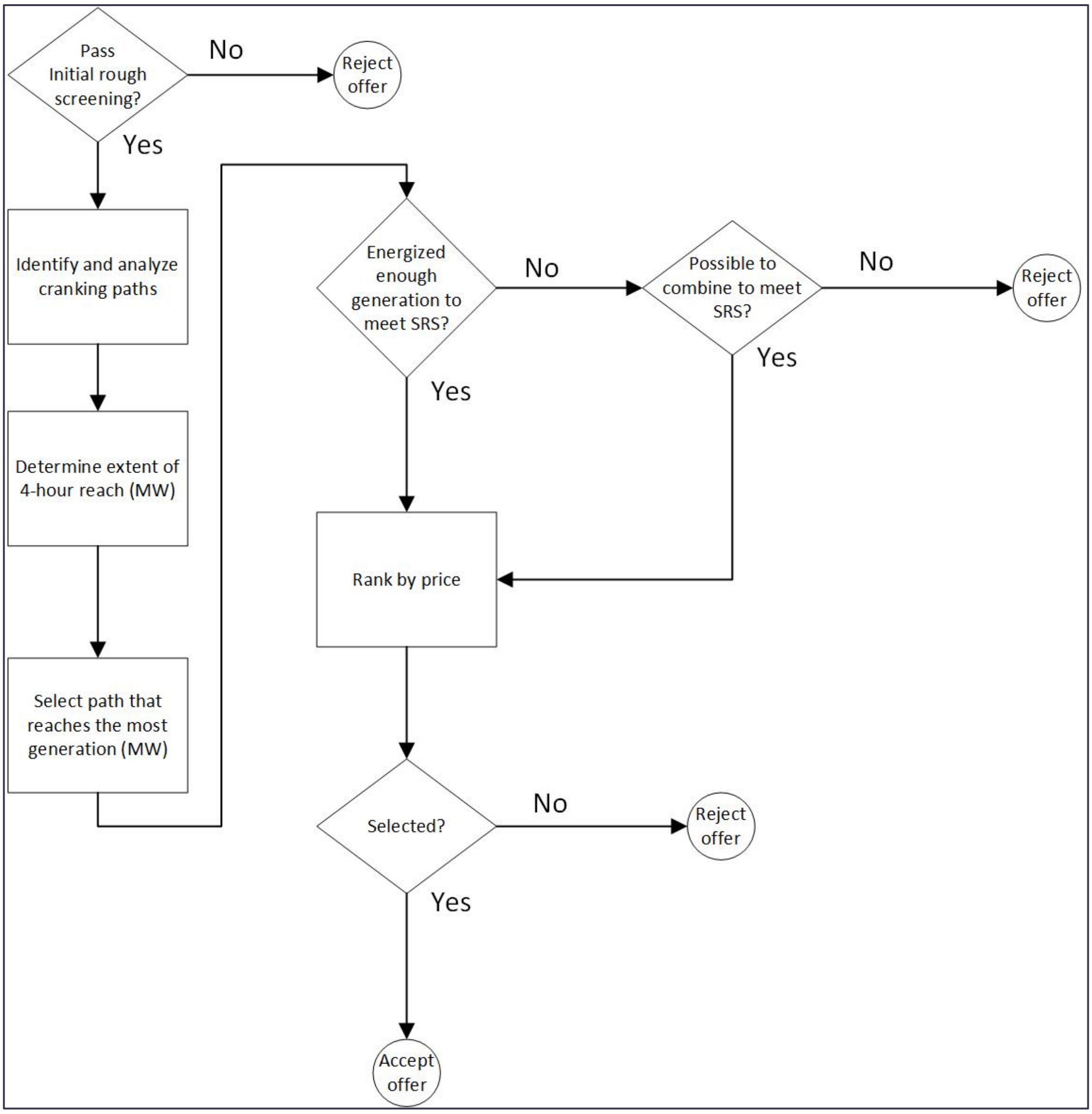
None of these variables was available using the previous method.

The bottom line is that the AEMO fully implemented the relevant DNV KEMA recommendations.

4.2 Analysis approach

An overview of the most important parts of the 2015 process is shown in Figure 2, below. Each submitted unit is evaluated for its suitability in providing SRAS.

Figure 2: 2015 SRAS submission technical assessment process



4.2.1 Initial rough screening

This step eliminates any obviously unqualified submissions. Submissions may be disqualified if they cannot provide power within four hours of energizing or if they are too small or connected at too low a voltage to be able energize any part of the transmission network.

We understand that only 4 of the 37 units submitted were disqualified in the rough screening.

4.2.2 Detailed analysis of cranking paths

This is, perhaps, the most important step of the 2015 regime. This step is the one that utilizes the dynamic modeling database and tools the AEMO developed.

Every reasonable cranking path was evaluated for each submitted generating unit. Often there was only one immediate path to reach transmission network. In most cases there were multiple transmission paths to reach additional generation.

With each identified path, the electromagnetic transient model was used to sequentially simulate energizing or activating transmission components. At each step the various dynamic variables were checked for any planning or operating criteria violations. If there were criteria violations then the path had reached its limit and no further generation could be energized.

If there were no violations the simulation moved to the next component in the path being tested.

When a new generator (usually its auxiliaries) was energized, its start-up time and ramp-rate were used to determine how much actual generating capacity could be counted toward the SRS four-hour limit. If, for example, a unit's auxiliaries were energized one hour into a start-up sequence, then only the amount of power that could be actively delivered to the transmission system in the next three hours (four hours from the initial SRAS unit start) would be counted.

The total amount of generation that could be delivered from all the energized generators within the SRS four-hour limit was the 'reach' of the particular SRAS being evaluated. This reach includes both the physical extent of the system energized and the amount of generation MW that can be delivered to the transmission system within the four-hour limit while recognizing the dynamic performance of the system.

This type of analysis was not possible with the previous method.

4.2.3 Determining the 4-hour reach of a cranking path

Each reasonable path was evaluated to see how much generation MW could be energized and brought to useful output with the four-hour SRS criteria. This is the *four-hour reach* for a combination of SRAS unit and cranking path.

4.2.4 Select the path that energizes the most generation MW

For each SRAS unit evaluated, the path that has the highest four-hour reach—the one that can start and make the most generation MW available within four hours—is selected for further evaluation. If the reach satisfies the SRS criteria it moves directly to the ranking step.

If the reach does not satisfy the SRS, it is set-aside until all the other submissions are evaluated.

4.2.5 Repeat process

The above process is repeated until all the submissions are evaluated.

4.2.6 Select SRAS submissions or combinations that meet the SRS

Once all the submitted units have been evaluated, those that satisfy the SRS are moved to the ranking step. Submissions that did not meet the SRS are reviewed to find any combinations that can meet the SRS. Any combination that met the standard is moved into the ranking step.

4.2.7 Rank successful submissions and combinations by cost

The successful submissions or combinations are ranked based on their submitted cost. The lowest cost submission or combination is selected as the winning SRAS tender(s).

There was one other consideration in the ranking process—some of the submissions only offered their units as a package. While the units were evaluated individually, that was not how they were submitted. In ranking the submissions by cost, these packages must be used because that was how they were offered. In some cases only one or two units in a package would be needed to meet the SRS; so there were extra, 'unnecessary' units included in these packages. There were packages that were not selected because the cost of the package was higher than some combination of other submissions.

The final result was that the AEMO selected the lowest-cost submissions that demonstrated their ability to meet the SRS through technically sound modeling.

4.3 AEMO compliance with the SRAS Guidelines

The AEMO developed SRAS *Guidelines* to comply with the requirements of the SRS.[6] The *Guidelines* set out the process by which AEMO will assess any offered or contracted SRAS.

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6. AEMO, SRAS Assessment Guidelines, Version 2, 15 December 2011.

While the *Guidelines* cover all aspects of the process, this review focuses on the simulation requirements.

The *Guidelines* require the AEMO to submit evidence regarding:

- The data, models and simulation method utilized;
- A record of all steps and repeated steps, if any, that were undertaken for the simulation;
- Where applicable, any deviations from the simulation program, giving reasons;
- Faults, problems and actions taken to address or resolve these matters;
- Relevant annotated operating diagrams that show key elements relating to the modeling and simulation;
- Relevant switching programs;
- Capability diagrams of the SRAS equipment;
- Relevant data sheets that include ratings and protection and control settings of the key elements;
- The capability of protection systems to clear faults in the SRAS equipment or at any point on the restart path when the only fault contribution is from the SRAS equipment and to state expected clearance times.
- Results of the simulations;
- Conclusions;
- Recommendations for improvement of the SRAS equipment or delivery of SRAS; and
- Any other matters that AEMO considers significant.

Specific simulation requirements are listed in Table A3 in Appendix A of the *Guidelines*. There are 18 groups of requirements as shown in Table 1. Additional details regarding the requirements can be found in the *Guidelines*.

Table 1: SRAS simulation requirements

	Requirement
1	Black-start capability, establish and energize a restart path and provide supply to the delivery point to assist the specified generating unit(s) to restart as described in the SRAS description;
2	Demonstrated black-start capability;
3	Demonstrated ability to operate at zero export load for a minimum period specified by AEMO or TTHL tripping scheme;
4	Demonstrated ability to close onto a de-energized bus;
5	Demonstrated ability to re-establish and energize a restart path to meet the minimum requirements specified by AEMO and sufficient to meet the requirements to provide supply to assist the specified generating unit(s) to restart;
6	Appropriate network controls and protection systems in place to avoid adversely affecting power system restoration;
7	Demonstrated ability to operate in a stable manner while network switching is performed and to meet the minimum requirements specified by AEMO;
8	Demonstrated ability to control network voltage within limits to meet the minimum requirements specified by AEMO;
9	Demonstrated ability to control power system frequency within limits to meet the minimum requirements specified by AEMO;
10	Demonstrated ability to control network voltage within limits to meet the minimum requirements specified by AEMO;
11	Have appropriate controls and protection systems in place to avoid adversely affecting the specified generating unit(s) while meeting the minimum requirements specified by AEMO;
12	Not have restrictions or limitations that have the potential to adversely affect power system restoration;
13	Supply loading levels sufficient to restart the Specified Generating Unit(s) while meeting the minimum requirements specified by AEMO;
14	Supply loading levels sufficient to restart the Specified Generating Unit(s) while meeting the minimum requirements specified by AEMO;
15	Control frequency while meeting the minimum requirements specified by AEMO;
16	Operate in a stable manner while meeting the minimum requirements specified by AEMO;
17	Control voltage while meeting the minimum requirements specified by AEMO; and
18	Reliability must be demonstrated in accordance with the system restart standard.

5 AEMO STUDIES—2015 METHOD

5.1 Results

5.1.1 SRAS submissions

The AEMO received 37 SRAS submissions from 11 companies. Of these, 4 submissions were connected at lower voltages and would not qualify for SRAS service because they could not energize the transmission system. A summary of the 33 submissions that were further evaluated is shown in Table 2. The total cost of these submissions was nearly $82 million.

Table 2: The 33 SRAS submissions

State	Submitting companies	SRAS submissions	Cost ($M)
Queensland	4	7	14.2
New South Wales	2	8	18.8
Victoria	4	8	26.6
South Australia	3	3	3.6
Tasmania	1	7	18.7
Total		33	81.9

5.1.2 Selected submissions

Of the 33 SRAS submissions 10 were selected based on the AEMO's technical and economic analyses as described above. The total cost for the accepted SRAS services was slightly more than $21 million. A summary of the accepted SRAS submissions is shown in Table 3.

Table 3: The 10 accepted SRAS submissions

State	Accepted companies	Accepted submissions	Cost ($M)
Queensland	2	3	3.9
New South Wales	2	2	7.2
Victoria	2	2	4.8
South Australia	2	2	2.3
Tasmania	1	1	3.0
Total		10	21.3

5.1.3 Sub-networks

A sub-network is a sub-area of a regional network as defined in NER for the purpose of acquiring SRAS.[7] These sub-networks are a means to ensure that the SRS can be met—especially in regard to the four-hour energizing requirements. In the absence of a competent analytical tool, using multiple sub-networks in some regions provided a conservative approach in setting SRAS requirements.

The SRS provides guidelines for determining electrical sub-networks, specifically, that: "The AEMO shall determine the boundaries for electrical sub-networks without limitation by taking into account the following factors:

- "The number and strength of transmission corridors connecting an area to the remainder of the power system;
- "The electrical distance (length of transmission lines) between generation centres;
- "The quantity of generation in an area, which should be in the order of 1,000 MW or more; and
- "The quantity of load in an area, which should be in the order of 1,000 MW or more."[8]

In 2012 the AEMO conducted a number of technical studies of the impact of treating Victoria and Tasmania as single networks and Queensland as two sub-networks. These studied showed that the SRS timeframes could be met under these conditions.[9]

The 2015 regime took the technical studies to a much higher level because of the improved modeling tools that were developed. These studies confirmed that only Queensland needed to have two sub-networks. All the rest of the regions needed only one sub-network.

5.1.4 Comparison to DNV KEMA review

The DNV KEMA review concluded that there was a need for multiple sub-networks only in Queensland. The 2015 technical study confirmed these conclusions.

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7. NER §3.11.4B.
8. System Restart Standard, Reliability Panel, 1 August 2013, §6.
9. Further details of these technical studies are set out in Appendix 2 of the System Restart and Ancillary Services Review Issues and Options Paper, the AEMO, 25 January 2013.

5.2 Selection process example—South Australia

In South Australia there were three SRAS submissions that passed the initial screening: Northern Power Station, Quarantine, and Dry Creek. Possible cranking paths were studied for each of these submissions. The path that had the greatest four-hour reach was selected for further analysis. The results are shown in Table 4.

Table 4: South Australia SRAS process example

Units energized and MW available within 4 hours	SRAS submission		
	Northern Power Station	Quarantine	Dry Creek
Northern Power Station	500	0	0
Quarantine	0	210	210
Dry Creek	0	155	155
Hallet PS, Port Lincoln, Mintaro	350	0	0
Osborne	0	180	180
Pelican Point	0	240	240
Total energized MW	**850**	**785**	**785**

The SRAS requirement for South Australia is 1,360 MW. As can be seen in Table 4, at least two submissions will be needed to meet the requirement. Also note that Quarantine and Dry Creek energize the same set of generating units so only one should be selected along with Northern Power Station.

The lowest cost combination was selected; in this case, Northern Power Station and Quarantine.

5.3 Comparison to previous method

Both the previous and 2015 processes seek to evaluate submissions to meet the SRS—in this they are the same. The improved analytic tools in the 2015 method drive the key differences.

The biggest difference between the two methods is the analytic analysis. The 2015 method determines the four-hour reach of each submission. The 2015 method analyzes specific cranking paths and the energized generation including generator ramp rates. The method finds the generators that a submission can energize and the amount that these generators' output can ramp up to within four hours.

The previous method estimated the ability of each submission to energize the nearest large generator or power plant and then determined how much those generators could produce within four hours.

The 2015 method evaluated cranking paths to whatever generators could be energized and provide power within four hours. This meant that a submission could meet the SRS by energizing multiple generation locations not just the nearest one. The previous method could sometimes double count generation.

An example of this can be seen in the South Australia example discussed, above. In that case both the Quarantine and Dry Creek submission have the same four-hour reach—they energize the same units. In the previous method both submissions might have been accepted and procured, while with the 2015 method only the less expensive one is accepted.

The other differences between the previous and 2015 methods are less important:

- Both methods perform a rough screening of submission at the beginning of the process. The previous method uses this step to make an initial valuation and ranking. In the 2015 method screening is solely to eliminate submissions that have no chance of meeting the SRS.
- The previous method ranks submissions at the beginning of the evaluation based on value/cost while the 2015 method ranks the options after they have been studied with the analytic tools. It is hard to see how the previous method could properly rank the value of a submission until the amount of generation it could support was determined.

6 CONCLUSIONS

The final results are reasonably similar to those estimated in the earlier DNV KEMA review—which suggested 6 sub-networks and 12 submissions, while the 2015 method found 6 sub-networks and 10 submissions were necessary to meet the SRAS standard.

The results are now backed by sound data and methodology, as discussed above. The previous method—as noted in the DNV KEMA review—was based on a greatly simplified (and inadequate) analysis.

The 2015 results demonstrate and document the ability of the selected SRAS submissions to fulfill the SRS. With the 2015 method, each proposed SRAS submission was evaluated to determine how much generation (MW) could be started to meet the SRS.

The total cost of SRAS services are reduced from $56 million/year with the previous method to about $21 million/year with the 2015 method.

These results demonstrate the AEMO's wisdom in developing the 2015 approach. The data and method are technically sound and properly applied allowing the AEMO to confidently improve the SRAS selection process; a process that resulted in significantly reduced costs.

The annual savings of nearly $30 million/year show the value of the AEMO's investment in developing the data, techniques and tools used in the 2015 regime.

6.1 Regarding AEMO actions

6.1.1 Conclusions—SRAS procurement guidelines

The AEMO developed SRAS *Guidelines* to comply with the requirements of the SRS.[10] The *Guidelines* set out the process by which AEMO will assess any offered or contracted SRAS. While the *Guidelines* cover all aspects of the process, this review focuses on the simulation requirements.

The simulation requirements are listed in Table A3 in Appendix A of the *Guidelines*. The table lists details regarding 18 specific and detailed requirements. The 2015 method clearly demonstrates that they have been met.

10. AEMO, SRAS Assessment Guidelines, Version 2, 15 December 2011.

6.1.2 Conclusions—sub-networks

DNV KEMA believed that the sub-network boundaries should be defined by likely transmission break points in meeting the first two SRS guidelines—number and strength of transmission corridors, and electrical distance. The break-points discussed in the DNV KEMA review were based on engineering judgment. The 2015 method allows a technically sound analysis to be made that can determine the efficacy and reach of the SRAS units regardless of sub-network boundaries.

The 2015 study indicated a need for two sub-networks only in Queensland. This is reasonable.

6.1.3 Conclusions—modeling

The AEMO developed an extensive database of essential system characteristics necessary to properly evaluate black-start cranking paths. The resulting database included essential transmission and generation characteristics.

The AEMO also developed a comprehensive modeling tool to use with the database. The tool evaluated not only the primary variables such as voltage and current flows but also a wide range of other variables that can affect a system restart.

The main features of the database and modeling tool include:

- The database
  - Transmission dynamic models developed using sophisticated design software;
  - Generation dynamic models from manufacturer data or developed based on similar units;
  - Generator start times and ramp rates;
  - Relay and breaker performance;
  - Transient voltage and power-dissipation ratings for various transmission components; and
  - Connections between the various components that for the network.
- The modeling tool
  - Builds on the capabilities the database provides;
  - Evaluates cranking paths one step at a time;

- Evaluates multiple parameters at each energizing step in the cranking paths;
- Parameters evaluated far exceed previous capabilities;
- AEMO staff evaluates performance of each cranking path following each energizing step;
- Properly considers generator start-up times and ramp rates after energizing each generator's auxiliaries; and
- Evaluates acceptable performance of all equipment and parameters at each step.

These are consistent with, or superior to, best practices in the industry. The quality and extent of the database and the additional measurements are excellent.

6.1.4 Conclusions—study method

The 2015 SRAS evaluation process is a significant improvement from the previous method. This is primarily due to the improved analytic data and method being used. The 2015 method and tools allowed much improved analyses of the SRAS submissions. This, in turn, allowed all the submission to be evaluated before they were ranked by value. The 2015 method also identified redundancies among some of the submissions that would have been missed with the previous method. The 2015 method could also identify submission combinations that could meet the SRS at lower cost than other options.

The study method includes these features:

- It is logical—the steps taken to develop the database and tools follow a logical pattern consistent with the goal of evaluating SRAS submissions;
- It is transparent—while there are a number of complex technical calculations involved, there are no hidden steps or procedures;
- It is consistent—it will yield the same results when used repeatedly and by other parties; and
- It is technically sound—it uses the best available approach for data and the analysis tools are modern and consistent with the best international practice.

Thus, the AEMO has developed a technically sound, robust method to evaluate SRAS submission and select SRAS submissions.

6.1.5 Conclusions—comparison to international practices

The 2015 SRAS model developed by AEMO staff is of equal quality to those used by the best ISOs and is more extensive than those used by most. The AEMO approach developed a database for the entire system required to evaluate the range of possible SRAS submissions.

All the better regional system operators and transmission owners use the same type of tools and analyses that the AEMO used. One aspect that distinguishes the AEMO method from nearly all others is the need to develop a full system model. This is a function of the NEM's unique SRS requirements and the resulting evaluation process.

Most utilities and system operators require black-start for nuclear plants and certain specific critical loads. In these cases only limited portions of the system must be modeled. Some of the biggest operators, however, also develop models for most of their system.

Regardless, they all use the same set of data and analytical tools as used by the AEMO.

6.2 Results

The results achieved by the 2015 method are a marked improvement from the previous method:

- They are reasonably similar to the earlier DNV KEMA review;
- They are now backed by sound data and methodology;
- They demonstrate the ability of accepted SRAS tenders to meet the SRS ;
- They reduced annual costs nearly 60%, from $56 million to ~ 20 million annually; and
- They demonstrated the wisdom in developing the new approach.

The results show the value of the AEMO's investment in developing the data, technique and tools for the 2015 regime

6.3 AEMC actions effective 1 July 2015

In its 2 April 2015 *Rule Determination*, the AEMC modified various terms of the SRAS to become effective 1 July 2015.[11] The AEMC changes are consistent with most of the DNV KEMA recommendations regarding assumptions and SRAS definition. The *Rule Determination*:

- Dropped the required NEM-wide blackout assumption;
- Removed primary and secondary SRAS definitions so that there is now only one class of SRAS;
- Confirmed that the AEMO has the freedom (and obligation) to determine any sub-network boundaries; and
- Confirmed that the AEMO is responsible for developing the SRAS guidelines.

These are consistent with the DNV KEMA findings.

The AEMC also clarified that a generator could be an SRAS for a neighboring sub-network if it was under contract for the service and that it was not providing SRAS in its own sub-network.

11. AEMC, *Rule Determination: National Electricity Amendment (System Restart Ancillary Services) Rule 2015*, 2 April 2015, page 11.

7 RECOMMENDATIONS

We make twelve recommendations for action listed below.

7.1 For action by the Reliability Panel

7.1.1 Regarding sub-networks

The purpose of sub-networks is somewhat opaque. The NER and SRS specify certain minimum requirements for sub-networks and the AEMO has established appropriate guidelines. What is lacking is any 'why'—an explanation regarding what conditions should require (or at least encourage) the AEMO to establish a sub-network. We believe the concept of sub-networks has outlived its usefulness.

Recommendation 1: The concept of sub-networks should be eliminated

- **a. The Reliability Panel should**
  - **i. Remove mention of sub-networks from §3 of the SRS;**
  - **ii. Revise the mention of 'sub-network' to "regional network" in §4 of the SRS;**
  - **iii. Remove §6 of the SRS regarding sub-networks; and**
- **b. The sections in the NER that address sub-networks should be removed including: §3.11.4A(c)(3), §3.11.4A(f), §3.11.4B, §3.11.5(n), §8.8.3(aa)(2) in part, §8.8.3(aa)(5), and the definition of *electrical sub-network*.**

The NEM transmission system covers a vast area that includes urban and rural areas. In some cases the distance between load centers is quite long. In such cases it is possible for the SRS to be met and not be able to energize or restart some portion of the system even after many hours. The database developed and the tools used in the 2015 method allow AEMO staff to evaluate if such situations are possible.

Recommendation 2: The reliability Panel should add a requirement to the SRS that requires the AEMO acquire SRAS such that there is a reasonable expectation of restoring the entire region within a day or two.

7.1.2 Regarding the 90-minute requirement in the SRS

As has been discussed above, the database developed and the tools used in the 2015 method allow AEMO staff to evaluate the SRAS submissions in a step-by-step way. This allows careful examination of the power system at each step in the process and the timing involved. The SRS now includes requirements for 90 minutes and four hours. The 90-minute requirement was appropriate in the previous method that used less sophisticated analyses techniques. It is no longer needed with the 2015 method because of the much better analytical tools being used.

Recommendation 3: The Reliability Panel should drop the 1.5 hours (90-minute) requirement from the SRS by removing the first bulleted item from §4.

7.1.3 Regarding SRAS diversity

Section 7 of the SRS addresses issues regarding diversity including electrical, technological, geographical, and regarding fuel sources.

7.1.3.1 Electrical diversity

> "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"

In its analyses, the AEMO assumes all transmission facilities are available but de-energized (blacked out). Under such conditions it is hard to understand what a "single point of electrical or physical failure" means. In its analysis, the AEMO energizes one element at a time. These could be subject to a single point failure all through the process. If applied literally, there would be no acceptable SRAS.

Recommendation 4: The Reliability Panel should re-evaluate this guideline—The electrical diversity guide should be dropped, or clarified.

7.1.3.2 Technological diversity

> "Technological - diversity in technologies shall be considered to minimise the reliance of services on a common technological attribute"

In theory, this guidance makes sense—it is better to have diverse technologies available. In practice, it will either be difficult to achieve or involve considerably increased costs. Most regional networks have a very limited range of possible black-start generation available. In Tasmania, they are all hydroelectric—there is no technological diversity. Other regions tend to be dominated by one or two technologies. For instance, it might seem logical to apply this to SRAS services based on trip-to-house-load generators. This is a common technology, but there is no reason to believe there is any common-mode failure among multiple units located at disparate locations.

Recommendation 5: The Reliability Panel should re-evaluate this guideline—The technological diversity guide should be dropped.

7.1.3.3 Geographic diversity

> "Geographical - diversity in geography shall be considered to minimise the potential impact of geographical events such as natural disasters"

The purpose of procuring SRAS is to assure that the necessary amount of black-start generation is available in each regional system to restart the system following a regional blackout. It is not to procure black-start capability for all possible conditions. In this context, the AEMO has established a set of assumed conditions to evaluate SRAS submissions. As such, applying a "natural disasters" element seems out of place. How is the AEMO to consider this guide? Clearly, if there are technically effective and equal-prices SRAS submissions, the AEMO should choose the ones that provide this diversity. But such equal-priced submissions don't often happen. This then leads to the question: How much extra should the AEMO pay for such diversity?

Recommendation 6: The Reliability Panel should re-evaluate this guideline—The geographic diversity guide should be clarified or dropped.

7.1.3.4 Fuel Diversity

> "Fuel diversity—"diversity in the type of fuel utilised by services shall be considered to minimise the reliance on one particular fuel source."

At first look, there may seem an obvious benefit in fuel diversity. If there were potential common-mode failures and little fuel storage at submitted units, lack of fuel diversity would be a justified concern. If submitted units have a reasonable amount of local storage, then a common mode failure is hard to find. Coal units in the NEM are mine-mouth units with inherent on-site storage. Natural-gas-fueled plants, on the other hand, could face possible pipeline disruptions affecting multiple units. If these units had on-site storage, however, they would be able to provide black-start capability within the limits of that storage.

Thus, fuel diversity is a potential concern only to the extent that submitted SRAS units do not have adequate local fuel storage. Otherwise, this requirement is unnecessary and will needlessly increase the cost of SRAS.

We believe 12 hours of local fuel storage for submitted SRAS units is enough for the AEMO to disregard fuel diversity in selecting submissions. The procured SRAS generation is intended to energize sufficient generation quickly enough that the system can be restored and the market return to operation. As such, SRAS units need only supply power for a limited time—enough to restore normal operation and generation dispatch by the market.

Recommendation 7: The Reliability Panel should re-evaluate this guideline—The existing fuel diversity text should be dropped and text added to exclude only generators that lack 12-hour local fuel storage.

7.2 For action by the AEMO

7.2.1 Regarding computer modeling and analysis

The 2015 computer database and analysis method is far superior to the previous method. This method has resulted in technically sound results that have significantly reduced SRAS costs. Going forward, the level of effort and cost of this approach will be less as the database has already been developed.

Recommendation 8: The AEMO should continue using the 2015 computer model and database, because they are far superior to the previous method.

7.2.2 Regarding black-start unit testing

The AEMO practice is to test potential SRAS units so as to demonstrate their ability to provide restart service. These tests are focused on the ability of the generator to produce useful power within the four-hour requirement. Other ISOs and transmission owner/operators have found it very useful to have black-start generators demonstrate that they can energize at least one transmission element beyond the generator's step-up transformer. Such tests expose the generator operators to issues related to controlling transmission voltages and synchronizing with the rest of the network.

Recommendation 9: The AEMO should require testing black-start units' ability to energize at least an initial section of transmission and then synchronize with the grid.

7.2.3 Regarding AEMO negotiations for SRAS

While not discussed above, effective 1 July 2015 the *Rule Determination* allows the AEMO to procure SRAS outside the tender process prescribed in the NER. The goal being that the AEMO procures SRAS at the lowest cost. (*Rule Determination*, page 10.)

Recommendation 10: The AEMO should develop a method for procuring SRAS outside the tender process as allowed in the *Rule Determination*. This effort should be done in concert with Recommendation 12: below.

7.2.4 Regarding bundled SRAS submissions

Generators have submitted SRAS offers as bundled groups of generating units. This should be a desirable way for generators to offer a group of units at a lower cost than the sum of the individual offers. In a truly competitive market this would be the most likely result of such bundling. In the NEM several regions are not very competitive for SRAS service and bundled submissions have seemed to reflect monopoly rents. One solution to such possible market abuse is to require more price disclosure in bids to the AEMO:

Recommendation 11: The AEMO should require that tenderers that offer bundled resources for SRAS must also offer each resource independent of the others. (This is linked with Recommendation 12: below.)

7.3 For action by policy makers

7.3.1 Regarding the competitive SRAS marketplace

The AEMC has made it clear that effective 1 July 2015 SRAS should be procured with the lowest possible cost:

> "Restart capability should be provided to consumers at an efficient price. These prices should reflect the costs of providing the service… Effectively competitive markets are the optimal way to deliver SRAS prices that reflect underlying costs…"(*Rule Determination*, page 9.)

> "The final rule provides AEMO with increased flexibility to fulfil its primary function of procuring SRAS at lowest cost... [And allows the] AEMO to procure SRAS more efficiently, by procuring SRAS whenever necessary, through whichever process it considers will enable it to meet the SRS at the lowest cost." (Page 10.)

> "AEMO must use reasonable endeavours to acquire system restart ancillary services to meet the system restart standard at the lowest cost." (Page 12.)

This goal of procuring SRAS at the lowest cost—cost that reflect underlying costs—are hampered by a critical restriction in the NER:

> "A dispute concerning any aspect, (other than the aspect of price), of a *system restart ancillary services* agreement or a call for offers conducted by *AEMO* for the acquisition of *system restart ancillary services*, must be dealt with in accordance with rule 8.2." (NER, §3.11.5(p))

The critical phrase being: "other than the aspect of price". This means the AEMO can negotiate but a potential SRAS supplier has no incentive to provide a lower, cost-reflective, price other than that provided by the competitive SRAS market. If there were a fully competitive market for SRAS this would be sufficient. And, on a NEM-wide basis there is likely sufficient competition for market forces to work.

Unfortunately, SRAS is procured on a regional basis—not NEM-wide. And, there is no competitive market for SRAS in at least three of the five NEM regions. One region has a single owner of all generation and two others have one black-start unit that is essential to meet the SRAS and *must be* procured by the AEMO. There is an obvious potential for abuse through monopoly rents in these regions.

Neither the AEMO, nor any other agency, now has the obvious ability to investigate or prevent such market-power abuse.

In theory, a high price for SRAS should be an incentive for other suppliers to come forward. In practice this does not work. Adding black-start capability to a unit is a very expensive option, and is effectively impossible for most generators. Recognizing that SRAS is an *ancillary* service, it is not used to justify constructing new power plants. So the market for SRAS is limited to generating units that were originally designed and built to provide black start (or any such new generating units that may enter the market). A market price for SRAS might be enough to incent some of the existing units to maintain their equipment and training to preserve this capability, but it is not enough to justify (or even influence) building new units.

Looking into the future, there is little encouraging news. All new generation being built in the NEM area is renewable solar or wind. These types of generators are not capable of providing the kind of black-start service required to meet the SRAS standards. Complicating this is the fact that existing conventional black-start generators are announcing their retirements. So, the present limited, non-competitive, regional marketplaces for SRAS are going to become less competitive.

Without remedy, the situation is ripe for monopolistic abuse.

We believe the AEMO should maintain its independence and not become embroiled in SRAS price disputes. Yet some remedy is called for.

Recommendation 12: A process should be developed to remedy any such monopoly abuse.

One possible remedy would involve:

a. **The AEMO being given the power to identify any SRAS submission that it feels may have costs far above actual underlying costs;**
b. **The AEMO being given the power to engage an independent consultant to review the cost of such a submission and determine if it is cost-reflective;**
c. **If the consultant finds that the submission price is considerably higher than the underlying costs, the AEMO may renegotiate the price of the subject submission.**
d. **If no acceptable price is reached, the AEMO may submit the case to binding arbitration by an independent arbitration panel.**
   The arbitration panel should be composed of three members who are engineers (or otherwise technically experienced and qualified) that are familiar with black-start generation operation and costs;
   i. **One panel member selected by the AEMO;**
   ii. **One panel member selected by the generator offering the submission in question; and**
   iii. **One panel member selected by the Premier of the state where the submission in question is to provide SRAS. (Keeping in mind that the cost of SRAS will be borne by the public in that state.)**