Draft Remedial Action Scheme Guidelines

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Important Notice

Purpose

AEMO has prepared this document to provide information about the specification, modelling, testing and review of Remedial Action Schemes and provide a reference of good electricity industry practice as defined in relevant areas of the National Electricity Rules, as at the date of publication.

Disclaimer

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1. Introduction

1.1. Purpose and scope

A Remedial Action Scheme (**RAS**) is an automated scheme, that following a contingency[1] on the power system, automatically takes action to prevent adverse outcomes such as cascading outages (for a comprehensive definition see section 1.2.1).

The purpose of these Remedial Action Scheme guidelines (**Guidelines**) is to articulate the general requirements and principles associated with the specification, modelling, testing and review of RASs for the National Electricity Market (**NEM**), and provide a reference of good electricity industry practice as defined in relevant areas of the National Electricity Rules (**NER**). The Guidelines also summarise relevant Rules obligations for Network Service Providers (**NSPs**), AEMO and Registered Participants in relation to the design, testing, maintenance and ongoing review of RASs as at the date of these Guidelines.

There is a wide range and increasing number of RASs across the NEM to manage credible and non-credible contingency events. Such schemes can improve asset utilisation, network access for generators and loads[2], reduce the impact and severity of events, and aid with recovery from such events. However, there is also potential for failure to operate or maloperation of RASs that lead to adverse system impacts, including cascading events and supply disruptions. In the context of the transforming power system and changing operational conditions, it is crucial that such schemes are reviewed to ensure they remain effective and continue to meet their design and performance requirements.

These Guidelines set out a consistent basis for definition of RASs relating to the following areas:

- Terminology.
- Design and testing requirements.
- Power system modelling requirements.
- Documentation requirements.

1.2. Definitions and interpretation

1.2.1. Interpretation

These Guidelines are not binding.

These Guidelines are not a substitute for the NER, or any guidelines, standards or procedures made pursuant to a provision of the NER. To the extent they conflict, these Guidelines should be read subject to the NER and those guidelines, standards or procedures.

[1] RASs most commonly operate following contingency events; however, some RASs are used to manage changes in power system quantities during system normal conditions that could otherwise result in exceedance of operating standards or damage assets.

[2] References to generators and loads throughout this document are also relevant to Integrated Resource Providers, as defined in the Australian Energy Market Commission (AEMC) Determination dated 2 December 2021, at https://www.aemc.gov.au/rule-changes/integrating-energy-storage-systems-nem.

1.2.2. Remedial Action Scheme

For the purpose of these Guidelines, the term Remedial Action Scheme (RAS) is used to collectively refer to emergency controls including:

- Those developed under Rule S5.1.8;
- Emergency frequency controls under Rule 4.3.2;
- Generator schemes established under S5.2.5.8; and
- Relevant protection systems[3].

A RAS is a scheme that, following a contingency[1], detects network conditions that have caused or may cause the network to depart from a satisfactory operating state and takes actions to prevent/arrest the divergence of network parameters from a satisfactory operating state or return the system to a satisfactory operating state.

RASs do not include primary plant protection (such as distance or overcurrent protection) with a purpose of clearing faults by isolating faulted network elements. RASs also do not include schemes or control systems with a primary purpose of maintaining satisfactory frequency or voltage during system normal conditions, such as voltage or frequency droop control on generators, automated reactive shunt switching based on local voltage measurement, and automated transformer tap changing.

1.3. Related documents

Table 1 lists key documents which define modelling requirements relevant for RASs.

Table 1 Related documents

Title	Location
Power System model guidelines	https://aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/Power_Systems_Model_Guidelines_PUBLISHED.pdf
Dynamic model acceptance test guideline	https://www.aemo.com.au/-/media/files/electricity/nem/network_connections/model-acceptance-test-guideline-nov-2021.pdf?la=en&hash=3287CA490B21CE0634D954440940232E
AEMO Standard for Power System Data Communications*	https://www.aemo.com.au/-/media/Files/Electricity/NEM/Network_Connections/Transmission-and-Distribution/AEMO-Standard-for-Power-System-Data-Communications.pdf

* At the time of publishing this consultation draft, the AEMO Standard for Power System Data Communications is under review.

1.4. Related requirements

Table 2 lists NER clauses relevant to these Guidelines.

In addition, NSPs have internal design, testing and compliance standards which are applicable to protection schemes including RASs.

3 Such as network protection schemes in place to manage credible contingency events.

Table 2 Related requirements

NER Requirement	Description
4.3.2	System security – Emergency frequency control schemes
5.7.4	Routine testing of protection equipment and NSP requirements to develop and maintain compliance programs for protection systems, and control systems that maintain or enhance power system stability.
5.12.1(b)(7) and 5.13.1(d)(6)	NSP review of interactions between emergency controls, emergency frequency controls, protection systems and control systems (published in its Transmission Annual Planning Report or Distribution Annual Planning Report).
S5.1.8 (including reporting requirements under 5.12.2(c)(9))	Defines NSP requirements to consider non-credible contingencies such as busbar faults, uncleared faults, double circuit faults, and multiple contingencies which could severely disrupt the network. For RASs associated with network elements such as wide area control schemes, frequency schemes or line overloading schemes, the design will usually be undertaken by the NSP (or NSPs for interregional schemes) in consultation with AEMO.
S5.2.5.8	Defines requirements relating to protection of generating systems from power system disturbances. For a RAS associated with a new generator connection, the scheme will usually be designed by the NSP in consultation with AEMO when establishing performance standards under schedule 5.2.5 of the NER.
4.15	Defines obligations for generators to develop, institute and maintain compliance monitoring programs to ensure ongoing compliance with performance standards (where applicable this encompasses performance standards relating to RASs).
5.2.3(d)(8)	Defines NSP requirements relating to modelling data used for planning, design and operational purposes.

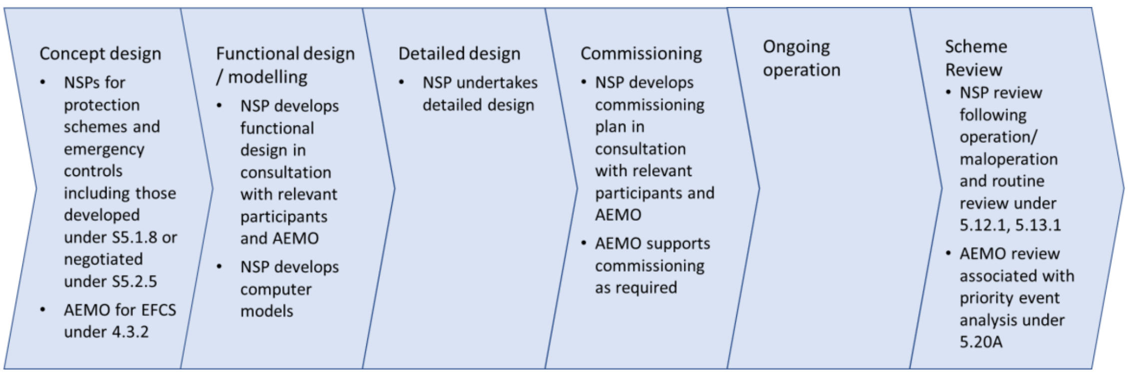
1.5. AEMO, transmission network service provider (TNSP) and distribution network service provider (DNSP) interactions

These Guidelines are relevant to emergency controls developed under Rule S5.1.8, emergency frequency controls under Rule 4.3.2, generator schemes established under S5.2.5.8 and relevant protection systems for managing credible contingency events. The Guidelines are intended to provide a reference for good industry electricity practice, including assessment criteria, modelling approach and information requirements to be developed and shared with NSPs and AEMO under relevant NER provisions.

1.6. Stages of scheme development

Figure 1 illustrates the development stages of RASs.

Figure 1 Scheme development stages



2. RAS types and terminology

This section summarises terminology used to describe different types of RASs. In general schemes should be named based upon their functionality and location for ease of reference.

2.1. Types of schemes

2.1.1. Runback scheme

A runback scheme is generally a scheme that monitors power system quantities such as thermal loading and initiates a reduction in output from load or generating plant (this may include batteries, high voltage direct current [**HVDC**] interconnectors, generators, loads or a combination). Generally the objective of such schemes is to mitigate or relieve thermal overloads or other limitations, often enabling utilisation of (N) system limits and short-term overload capability of assets such as lines and transformers. This type of scheme usually operates in a few seconds to tens of seconds and in some cases minutes.

The advantage of such schemes is that they enable the controlled device to remain connected and continue to support system voltage control and able to increase output once the system is restored to support system load (in the case of a generator, for example) or continue to be supplied (in the case of a load).

These schemes go by other names in the NEM including:

- Ramp down schemes.
- Generator control schemes.
- Runback control schemes.

See also section 2.1.3, which describes System Integrity Protection Scheme (**SIPS**) schemes which may utilise similar functionality to runback schemes.

2.1.2. Tripping/intertripping/transfer trip scheme

A trip/intertrip scheme generally monitors the status of power system element circuit breakers and directly intertrips a load, generator or other element such as lines or transformers after detecting tripping of the monitored elements[4]. In some cases, alternative approaches may be used, such as monitoring other network quantities (power flow, voltage or frequency) and use other protection such as over-current protection (depending upon the network topology).

Intertrip schemes are generally designed to cater for specific contingencies (such as the outage of a parallel circuit to manage thermal loading, or the outage of an infeed to manage system strength stability). This type of scheme generally requires the greatest level of scrutiny as they can have the greatest impact on power system security, and can be difficult to manage during planned (and unplanned) network outages.

These schemes have historically been represented by other names in the NEM, including:

[4] Such schemes may trip, for example, a portion of a load or generation facility by tripping a single supply transformer, feeder or other element, based upon scheme requirements.

- Constraint management schemes.
- Fast trip schemes.
- Line overload load shedding schemes.
- Line overload protection schemes.
- Overcurrent protection schemes.
- Overload control schemes.
- Overload guards.
- Overload management schemes.
- Overload schemes.
- Overload shedding schemes.
- Plant overload protections.
- Protection schemes.
- Special Control Schemes.
- System overload control schemes.

2.1.3. System Integrity Protection Scheme

While less common at present, a SIPS generally refers to a scheme that enables greater asset utilisation or improves system security for (N) operation or in specific outage conditions, or to mitigate system risks associated with non-credible contingency events such as multiple contingencies or N-2 events. For example, it may allow transmission lines to be operated at higher thermal loading, or prevent an inter-regional or intra-regional separation following certain contingencies. This may also include schemes that increase output from battery systems or other generating plant.

2.1.4. Anti-islanding scheme

An anti-islanding scheme removes a generator from service in response to the generator becoming islanded within part of the network. Such schemes trip the generator to avoid creating an electrical island and to mitigate possible issues to network and customer equipment. In the context of the RAS Guidelines, anti-islanding schemes are automated schemes as distinct from passive monitoring (such as Vector shift and rate of change of frequency [**RoCoF**] protection).

2.1.5. Frequency control scheme

A frequency control scheme trips generation and/or load in response to a network event that could cause or has caused an imbalance in electrical supply and demand. These schemes may also include rapid active power responses from inverter-based resource (**IBR**) technologies. Generally, such schemes are designed to limit the frequency peak or nadir (minimum) following a trip of multiple generating units or loads, or when a region is separated from the rest of the system. Schemes in this category include under-frequency load shedding (**UFLS**) schemes, emergency under-frequency schemes, over-frequency generator shedding (**OFGS**) schemes, and generation/load tripping schemes.

The NER define a specific term *emergency frequency control scheme* (**EFCS**). Responsibilities for the various aspects of EFCSs are defined in the NER, including (but not limited to) clauses 4.3.1, 4.3.2, 4.3.4 and S5.1.10.1a.

2.1.6. Wide area scheme

A wide area scheme uses measurements from multiple sites and assets to coordinate a single control routine. For example, using measurements from multiple phasor measurement units (**PMUs**) to identify system instability and trigger a control response.

These schemes go by other names in the NEM including:

- Wide Area Protection Scheme (**WAPS**).
- Wide Area Monitoring, Protection and Control (**WAMPAC**).

2.1.7. Over- and under-voltage schemes

A scheme which automatically corrects an over or under-voltage condition following a contingency through control of susceptance (that is, the switching of capacitor banks, reactors and/or loads, lines or other network elements, or control of generators).

2.1.8. Auto changeover

One or more elements in a power system are automatically switched into service following a network event or condition in order to maintain reliable supply. These often include an acceptable period of supply interruption during switching time.

These schemes go by other names in the NEM including:

- Auto close schemes.
- Normally open auto close (**NOAC**) schemes.

2.1.9. Other schemes

The above is not a comprehensive list of types of schemes, and there may be other variants, or schemes that use a combination of the above as part of primary and backup protection functions to achieve the desired outcome[5]. In some cases schemes are described in terms of the technology used for scheme operation, the issue the scheme is addressing, or the quantity being controlled by the scheme.

Some scheme types overlap between the types of schemes listed above (for example, a wide area scheme may also be an EFCS), and some RASs in the NEM that would fall under the above list of scheme types use more broad terminology including:

- Emergency control schemes.
- Control schemes.
- System Protection Schemes.

[5] For example, a primary generator runback scheme with delayed backup inter-trip function, and use of protection devices versus supervisory control and data acquisition (SCADA)/energy management system (EMS) control.

2.2. RAS naming conventions

New RASs should be named to convey the type of scheme, generally based upon the RAS action, and should include some descriptor to indicate its location or the plant controlled.

This is important to avoid multiple schemes having the same or very similar names. AEMO should be engaged in the initial naming of a proposed scheme, to ensure its name is clear and does not overlap with another scheme name, including when shortened to an acronym.

It is noted that some schemes can involve multiple actions at multiple locations, which will not all be able to be conveyed in a name. Judgement will be applied to balance descriptiveness with practicality.

Key definitions relating to RASs are included in Appendix B.

3. RAS performance and design

3.1. General requirements

The application of RASs has the potential to increase asset utilisation, improve resilience, and assist with mitigating the impact of certain power system events. Careful consideration is required to ensure that RAS design is consistent with the principles of the NER[6], is not overly complex, and does not present an unacceptable level of risk to the power system. Planned and forced outages should also be considered in their design[7].

Appendix A provides a guide for assessing new RASs and the types of criteria to be applied by NSPs and AEMO.

As part of the assessment, the net load/generation contingency size should be determined and documented in the advice to AEMO and NSP control rooms. When designing a new scheme, effort should be taken to minimise the cumulative impact of the new scheme and any existing schemes or controls. This may also consider the potential to apply operational constraints (in addition to RAS operation).

The RAS should be designed to be robust such that changes in the power system (such as differences in actual operational conditions, changes in demand, or changes in rooftop photovoltaics [**PV**]) should not require a significant scheme review.

A RAS shall limit the post-disturbance currents, power flows, voltages or other relevant parameters on the system to be within all applicable ratings without a need for real-time operator intervention (other than acknowledging RAS operation based on real-time alarms). Therefore, operators should generally not be required to manually arm/disarm such schemes as system conditions change, unless there is a notable change in network topology.

For Generator or Customer RASs, they are documented in the relevant performance standard in adequate detail to ensure the performance and compliance is adequately defined.

[6] For example, it would not be appropriate for a generator to trip for credible network contingencies where the generator could otherwise tune its control system to ride-through the disturbances and support fault recovery under S5.2.5.5.

[7] For RASs designed to manage prior outages, it may be necessary to consider subsequent outages.

3.2. Operational requirements

In the development of the scheme, AEMO should be consulted regarding:

- Supervisory control and data acquisition (**SCADA**) monitoring of scheme status and status monitoring[8].
- Ability to remotely enable /disable schemes.
- Data quality checks.
- Actions upon scheme failure (including failure of inputs and outputs).
- PMU data requirements (if PMUs are used) and time synchronisation.
- Impact on power system limits/constraints.
- Impact on system resilience.
- Cyber security requirements.

3.3. Design guidelines

RAS design should consider duplication (including redundant communications, relays and signalling) and conform with relevant cyber security requirements. The level of duplication is to be informed by the outcome of failure mode effects and criticality analysis (**FMECA**) and as low as reasonably practicable (**ALARP**), with consideration of how power system risks will be managed if the scheme is unavailable or fails to operate.

Part of the RAS design phase is to demonstrate the requirements/benefit for the RAS and what occurs if it is unavailable. This should also include evaluation of the associated risk of failure to operate[9], spurious operation[10], and inadvertent interaction with other schemes. The scheme's impact on the network should also be evaluated against the cost and complexity of the scheme. For plant participating in a RAS (such as a load or generator) it should be ensured that trip signals are 'tamper proof' and signalling and trip coils etc cannot be inadvertently disconnected.

Table 3 can be used to categorise RASs according to the consequences of three scheme failure modes – failure to operate, spurious operation, and inadvertent interaction with other schemes. The consequences of each of these failure modes are considered across three different system aspects – infrastructure, market, and compliance.

Therefore a consequence assessment of a RAS using Table 3 gives nine consequence ratings (three failure modes times three system aspects). The overall consequence rating for the RAS should be taken as the most severe of the nine consequence ratings. This can be used to inform design and testing of the RAS as per the information in Table 4 and Table 5. Appendix C provides example consequence rating assessments.

[8] Such as where a scheme is inoperable and its functionality cannot be guaranteed due to failure of any component of the system, including but not limited to the dual protection and communications system, loss of SCADA controls and inputs, and frozen data.

[9] "Failure to operate" means the scheme did not operate (either completely or partially) when it should have to achieve the desired outcome. This could be due to equipment failure, or an error or limitation in the scheme design.

[10] "Spurious operation" means the scheme operated (either completely or partially) when it should not have to achieve the desired outcome. This could be due to equipment failure, or an error or limitation in the scheme design.

Table 3 RAS consequence categories for 1. failure to operate 2. spurious operation, and 3. inadvertent interaction with other schemes

Consequence rating	Infrastructure	Market	Compliance
1 – Catastrophic	Permanent or long-term damage or affect or rectification not possible.	Loss of supply to > 50% of customer demand in any one jurisdiction or > 25% across multiple jurisdictions.	Breach of compliance obligation with severe impact (for the purpose of these Guidelines, for example, a non-satisfactory operating state on multiple TNSP networks)
2 – Major	Significant damage or affect, difficult rectification.	Loss of supply to > 25% of customer demand in any one jurisdiction or > 10% across multiple jurisdictions.	Breach of compliance obligation with high impact (for the purpose of these Guidelines, for example, a non satisfactory operating state on plant of wide area of one TNSP network, or on plant of multiple DNSP networks).
3 – Moderate	Measurable damage or affect, easy rectification.	Loss of supply to > 10% of customer demand in any one jurisdiction or > 5% across multiple jurisdictions.	Breach of compliance obligation with moderate impact (for the purpose of these Guidelines, for example, a non satisfactory operating state on plant of wide area of one DNSP network, or on plant of localised area of one TNSP network).
4 – Minor	Measurable damage or affect, no rectification required.	Loss of supply to > 5% of customer demand in any one jurisdiction or > 2% across multiple jurisdictions.	Breach of compliance obligation with minor impact (for the purpose of these Guidelines, for example, a non satisfactory operating state on plant of localised area of one DNSP network).
5 – Immaterial	No measurable damage or affect.	No restriction of supply. No disruption to markets.	No breach of compliance obligation.

3.4. Design principles

Table 4 summarises design principles based upon the consequence rating of each RAS.

Table 4 Design principles for categorised schemes

Design Guide \ Consequence rating	1	2	3	4	5
Duplicated[A] and Protection Grade	✓	✓	Note B	Note B	Note B
High Availability on both schemes (8 hours down time each year[C])	✓	✓			
High Availability on single scheme (8 hours down time each year[C])			✓	✓	✓
Route diverse[A]	✓	✓			
Telemetry including RAS health and status to NSP and AEMO	✓	✓	✓	✓	✓

A. See definition in Table 7.
B. In some cases scheme duplication may be implemented through an available backup communications channel such as SCADA as an alternative to having no duplication. Or a heart beat check combined with runback in the event of communications failure is used in some circumstances.
C. This amount of down time is a starting point for consideration. Longer down times may be considered with appropriate risk assessment and mitigations (for example constraining generator while runback scheme is unavailable, or using a heart beat check with runback in the event of communications failure).

Timing requirements will depend on:

- The power system phenomena the scheme is seeking to manage (for example, thermal overloading versus stability limits).
- Coordination with other protection systems.
- Coordination with backup scheme (if applicable).
- Coordination with other RASs.

3.5. RAS testing

3.5.1. Commissioning tests

Generator/Customer RAS

Testing of a generator or customer RAS will be done as part of the commissioning program. For generators, this is generally before proceeding above initial hold point testing at low active power output levels. If the RAS is required for the generator to generate above a certain threshold, the RAS should be fully tested before exceeding this threshold and relevant dispatch constraints updated. Where analogue inputs are used to trigger the scheme, thus requiring a certain amount of generation, these inputs should be simulated.

Network RAS

For RASs that relate to network elements, testing often requires the system to be in a particular state. Test plans should be created in consultation with AEMO and, where possible, actual system tests should be used.

Where system tests are not possible due to the size of the impact or the inability to set up the required conditions, hardware in the loop testing, offline testing and point to point testing with increased monitoring may be appropriate.

3.5.2. Testing guidelines

The relevant NSP should coordinate with affected parties to design, install, test, document and maintain and review the RAS in line with its obligations and internal procedures. The table is not comprehensive and test requirements should be defined on an individual scheme basis, and may include point to point testing, hardware in the loop testing, bench testing etc.

Table 5 Testing guidelines

Consequence rating / Testing Guide	1	2	3	4	5
Hard Test	To the extent practical	Where practical			
Functional Test	✓	✓	✓	✓	✓
Timing Test	✓	✓	✓	✓	✓
Secondary Test	✓	✓	✓	✓	✓
Commissioning Test	✓	✓	✓	✓	✓

3.6. RAS review

The actual performance of existing and new RASs is documented and periodically reviewed by the NSP and AEMO.

Generally schemes are reviewed:

- As part of an incident review under clause 4.8.15 of the NER;
- Every year according to obligations under clause 5.12.1 of the NER or 5.13.1 of the NER;
- In accordance with protection review; and
- When new schemes/network/generation/load are proposed that could impact the operation, effectiveness or requirement for the RAS.

Where a maloperation occurs, the NSP liaises with AEMO to identify corrective actions required to manage power system security. This may result in a scheme being reviewed or disabled by AEMO with a potential impact on constraints applied to those generators included in the scheme.

AEMO and NSPs routinely review schemes as part of routine planning requirements, in particular under 5.12.1(b)(7), 5.13.1(d)(6) and 5.20A. This should consider changes in the power system or operational conditions that could lead to ineffective or spurious operation of RASs. This will be determined on a case by case basis and may involve:

- Explicit modelling of RASs and relevant protection systems.
- Analysis in appropriate analytical package(s).
- Development of future cases to represent expected network topology and operational conditions.
- Assessment of credible and non-credible contingency events.

Where multiple resources participate in a RAS, AEMO and NSPs should identify if there is a requirement for future connections to participate in that scheme. This is anticipated to reduce the need for wholesale reviews of schemes and modification of connection requirements post-connection.

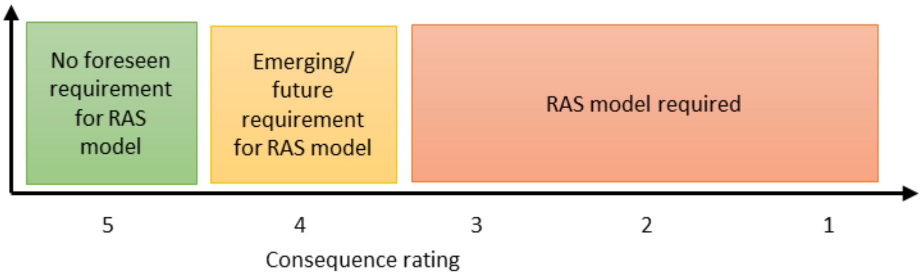
4. Modelling and documentation requirements

4.1. Modelling requirements

The need for models of RASs is evolving as their individual and combined impact on power system operations and security becomes increasingly more important. The purpose of this section is to outline RAS modelling requirements where it is determined that they are needed for power system studies. The figure below illustrates the principles that should be applied when determining the need for a model of a particular RAS, which is to be developed by the RAS owner.

As a general rule, models should be developed for new or modified schemes, except where they are of low complexity and low impact on the system (for example, local anti-islanding schemes). Consideration should be given not only to whether the RAS operating on its own is low impact, but also whether any contingencies (credible or non-credible) could trigger the RAS in combination with other RASs, leading to a material impact on the system.

Figure 2 Determining RAS modelling requirements based on consequence rating



RAS models should encompass:

- Communication, measurement, filtering and processing delays (for example, intentional time delays like timer settings, or inherent delays like relay operating times).
- Calculation algorithms and logic/tripping sequences.
- Output actions including associated delays.
- Parameters, signals and status to be monitored.

4.1.1. RMS modelling requirements

Where possible, RAS models should be represented with standard objects from the PSSE model library. If detailed modelling and representation of a RAS is required, model development should be undertaken using Fortran code unless agreed otherwise with AEMO. Refer to the Power System Model Guidelines[11] for detail regarding modelling requirements.

The model should be written to be compatible with foreseeable disturbance simulations, for example trip of a monitored network element. Model documentation and error messages should also warn of simulation actions that may interfere with correct model operation, such as inserting a dummy bus into a monitored line to apply a fault.

On a case by case basis, AEMO may consider alternatives to modelling the RAS with a Fortran-based model, for example using generic PSS®E models where appropriate or a python file (for a scheme triggered solely by element outages).

4.1.2. EMT modelling requirements

Where possible, RAS models should be represented with standard objects from the PSCAD™ model library. If detailed modelling and representation of a RAS is required, development should be undertaken using Fortran code or unless agreed otherwise with AEMO. Refer to the Power System Model Guidelines for detail regarding modelling requirements.

On a case by case basis, AEMO may consider alternatives to modelling the RAS with a PSCAD™ model, for example modelling simple topology based schemes using a scripted approach.

[11] See https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/power_systems_model_guidelines_published.pdf.

4.1.3. EMS modelling requirements

The following should be provided to AEMO and/or affected NSPs to enable EMS modelling, if it will act on plant that is visible within their EMS system, or could materially affect their networks or operational zones:

- Model user guide including flow chart of operation of the scheme including timing of events and actions and pseudocode.
- Details of the applicability of RASs including any associated limitations.
- RAS study report including details of studies undertaken to verify scheme performance.
- Required telemetry as agreed with AEMO and/or NSP.

5. Documentation

The following sections outline AEMO's expectations for documentation of RASs and sharing of documentation with relevant parties.

5.1.1. Operational documentation

All proponents of RASs are to provide detailed documentation about the inputs, outputs, impacts and operating conditions, as well as operationally monitored quantities and triggers for scheme operation (including associated logic diagrams). Documentation should be maintained and updated, including when network topology changes impact the scheme operation or design.

Documentation is to be provided to AEMO that is appropriate for operations as well as planning purposes prior to the scheme being armed[12].

AEMO and NSP Control Room Staff should have clear advice on what alarms will be provided if the scheme fails, as well as for when the scheme has triggered and the scheme has operated.

If applicable, flow charts showing the decisions and conditions required should be provided.

In general, scheme documentation would include details regarding:

- Enablement management.
- Operational modes.
- System impact.
- Impact on plant loading and fault levels.
- Impact on stability.
- Limitations (for example, limitations on the number of operations per year based on generator/load participating in the scheme).
- Interaction with other schemes.

[12] As a general rule, such information should be provided six weeks prior to scheme enablement to enable update of operational documentation and procedures.

- Managing RAS outages.
- Impact of network outages on the scheme.
- Constraint requirements when RAS is in/out of service.
- Whether there is real-time monitoring of the scheme, including after the scheme has operated and if it operated as expected.
- Actions required during planned maintenance/unplanned outages of network elements.
- Actions required during planned maintenance/unplanned outages of the scheme.
- Scheme redundancies.
- For critical schemes, availability requirements and plans for ongoing compliance testing.

5.1.2. Scheme interactions

Throughout the RAS design process and routing planning activities (including joint planning), possible interaction with other RASs within a region and with other regions of the NEM should be considered and any interactions documented. This includes possibility of simultaneous failure (communications or otherwise), similar inputs and outputs and susceptibility to non-credible events, as well as the impact of operation of other RASs.

Appendix A. RAS assessment criteria

Table 6 summarises the assessment criteria that can be used when reviewing proposed new or modified RASs in the NEM. It is based on requirements of the NER and has been developed with reference to the CAISO planning standard[13] and in consultation with NSPs. It is envisaged that NSPs would consider these criteria when reviewing proposed RASs in the NEM and consulting with AEMO under NER S5.1.8.

It is anticipated that the assessment against each of these criteria would be based on the consequence rating and design of the scheme, for example whether the scheme is designed for:

- System normal, credible contingency events,
- System management during prior planned or forced outage events,
- Wide area monitoring protection and control, or local area monitoring protection and control,
- Non-credible contingency events such as double circuit outages, or
- Transmission network or distribution network.

It is emphasised that these criteria are for guidance and are not compulsory standards. Specific aspects of the criteria may be more suited to some of the above applications than others; engineering judgement should be applied accordingly in accordance with the principles and requirements of the NER. In general, these criteria are intended to be applied more flexibly to RASs that manage non-credible contingencies or prior outages than RASs that manage system normal credible contingency events. Also greater flexibility is intended for RASs on distribution networks than on transmission networks, based on the (likely) consequence rating of such schemes.

Table 6 RAS assessment criteria

Item	Criteria	Assessment
1	The overall reliability and security of the system should not be degraded after the combined addition of the RAS (consistent with NER cl. 5.1A.2).	
2	The RAS needs to be highly reliable. It should not be considered credible for the initiating event to occur and the RAS to fail, see also section 3. Relevant approvals need to be provided by the NSP, affected NSPs and AEMO.	
3	Generator RASs can efficiently address system limitations in some circumstances however it is not generally acceptable to implement generator RASs for: (i) Contingencies on a different flow path to the connecting generator, and (ii) Contingencies on multiple flow paths. For generator RASs – disconnection for contingencies that do not meet these criteria is considered to be inconsistent with fault ride-through requirements under clause S5.2.5.5 of the NER.	
4	The total net amount of generation reduced as a result of a credible contingency event, accounting for operation of RAS(s), by a RAS for a single contingency cannot exceed 100 MW or other reasonable limit agreed by the NSP and AEMO, taking into account impact on other limits (e.g. frequency stability, voltage stability, voltage control) as defined in S5.2.5.4 and S5.2.5.5 of the NER. The assessment should	

[13] See https://www.caiso.com/Documents/ISOPlanningStandards-September62018.pdf.

Item	Criteria	Assessment
	take into account the reasonableness of using dispatch constraints to limit the maximum contingency size accounting for the RAS. For reference, NER clause s5.2.5.5(k) states the following: …unless *AEMO* and the *Network Service Provider* agree that the total reduction of *generation* in the *power system* due to that fault would not exceed 100 MW, or a greater limit based on what *AEMO* and the *Network Service Provider* both consider to be reasonable in the circumstances, NSPs consult with AEMO regarding the total net amount of load or generation tripped by a RAS for a non-credible contingency. AEMO's assessment would be based on assessment of the impact of the non-credible contingency event. The net load or generation is determined as the difference between load and generation reduction due to operation of the scheme[14]. The assessment should also consider the type of generation disconnected and the impact on other system services such as frequency control, system strength and inertia. Note: This criteria is expected to be assessed with respect to the feasibility and reasonableness of using operational constraints to limit the maximum contingency size for credible contingency events.	
5	The following risk and consequences of RAS failure should be considered: • Cascading outages beyond the outage of the facility or facilities that the RAS is intended to protect: For example, if a RAS were to fail to operate as designed for a single contingency and the transmission line that the RAS was intended to protect were to trip on overload protection, then the subsequent loss of additional facilities due to overloads or system stability would not be an acceptable consequence. • Voltage instability, transient instability, control system interactions or small signal instability: The consequences can be so severe that they are deemed to be unacceptable results following RAS failure.	
6	The overall risk assessment for the RAS should also consider planned and unplanned outages. What occurs following outages, for example: • Is the user required to reduce output or disconnect? • Is market intervention required e.g. using constraints? • For unplanned outages, how long following the outage should action be taken?	
7	Close coordination of RASs is required to eliminate cascading events. Single network elements should not be associated with multiple different RASs. Except in some cases two schemes of different types or which are enabled under different conditions might be considered.	
8	As a general guideline, for schemes associated with a specific plant (e.g. load/generator): • There should be no more than four local contingencies (single or credible double contingencies/protected events) that would trigger the operation of a RAS (see also item 3). • Other than for wide area monitoring schemes, RASs should not be monitoring more than four system elements or variables. A variable can be a combination of related elements, such as a path flow, if it is used as a single variable in the logic equation. • Generally, a generator RAS should only monitor facilities that are connected to the plant or to the first point of interconnection with the grid. Monitoring remote facilities may add substantial complexity to system operation and should be avoided. • In general, a RAS should not require real-time operator actions to arm or disarm the RAS or change its set points unless this is considered necessary to mitigate the potential for maloperation during circumstances where the scheme is not required to operate. • The risk of interaction/cascading operation with other schemes should be assessed as acceptable.	
9	If the RAS is designed for new generation interconnection, the RAS may not include the involuntary interruption of load (unless contracted).	

[14] For example, for a cut-set with power flowing north to south, a scheme may trip generation in the north, and load in the south, to avoid overloading lines in parallel to that cut-set, and also minimise broader system frequency impacts.

Item	Criteria	Assessment
10	Action of the RAS shall limit the post-disturbance current, power flows, voltage, frequency or other relevant parameters on the system to be within all applicable limits and shall ultimately bring the system to within the long-term ratings of the transmission equipment without a need for real-time operator intervention.	
11	The expected frequency of operation of the scheme should be considered in the review of RAS proposals, for example if the scheme design is such that it operates frequently and would adversely impact power system operations, it may not be considered acceptable.	
12	Assessment of potential adverse impact on power system security or quality of supply to other network users (under clause S5.2.5 of the NER) following disconnection for loss of system strength remediation scheme should be acceptable.	
13	The response does not exceed system standards or adversely impact other Users within the RAS operation time.	
14	The proposed RAS is demonstrated to be required through appropriate analysis including appropriate consideration of power system performance, technical limits and alternative options (such as minor network upgrades, control system tuning etc).	
15	The scheme design (e.g. runback versus intertrip) should be determined based on the nature of the applicable contingency(s) and resulting issues (e.g. thermal overload versus stability). Runback is generally preferred over intertrip, unless intertrip is necessary to achieve the desired outcome (e.g. runback would be too slow, or scheme needs to trip IBR due to inadequate system strength).	
16	Planned and forced outages and associated operation of the RAS should not have a material adverse impact on generation reserves (considering the impact of RAS operation and subsequent actions to resecure the power system). Such proposals should be assessed with respect to the principles of clause 5.1A.2 of the NER.	
17	Other events that lead to the outage the RAS is designed to manage, beyond system normal credible contingencies, should be assessed and designed for (e.g. trip of busbar, line end CB open, other non-credible events).	
18	The consequence of spurious RAS operation should not have an adverse impact on power system security or quality of supply to other network users , taking into account estimated likelihood and impact.	
19	Assessment of scheme operation during prior outages should be undertaken to determine any changes to the scheme or operational requirements (e.g. constraints on generators participating in a particular scheme) required during outages.	
Overall recommendation		ACCEPTABLE/ **NOT ACCEPTABLE**
Endorsed		ACCEPTABLE/ **NOT ACCEPTABLE**

Appendix B. Key definitions

Table 7 Key definitions

Definition	Description
Bench test	For example, testing of protection equipment in a test environment by simulating inputs to the relay from (simulated) monitoring equipment or application of signals from test equipment.
Commissioning test	Involves testing the wiring, supply and earthing of the RAS panel.
Duplicated	All components of the communication system are duplicated (including, for example, batteries, chargers, multiplexers).
Functional test	Tests the primary and secondary systems involved in executing the system protection scheme.
Hard test	Conducting a network event and testing the actual response of the system under controlled conditions.
Hardware in the loop test	Involves connecting the RAS hardware to a virtual environment, such that a power system disturbance can be modelled in a simulation package (e.g. RTDS, PSS®E, PSCAD™), relevant simulated measurements are fed into the RAS and the resultant RAS output signals are then observed and compared to expected outcomes.
Heart beat	Refers to routine signal checks to check scheme status.
High speed	Scheme complies with the critical clearance times outlined in the NER. Such schemes are implemented using protection-grade equipment, as opposed to schemes implemented in SCADA/EMS systems which typically operate over a period of several seconds or more.
Offline testing	Testing of equipment in an offline environment (i.e. not online).
Point to point testing	Testing from one relay/communication device to another (rather than full end to end testing). Typically for such tests relay trip coils are removed to prevent operation of field devices.
Route diverse	Distinct communication paths that have no common geographic point of failure.
Secondary test	Using a test set to assess the thresholds, inputs, outputs, alarms and links of the Intelligent Equipment Device (IED) used to execute the system protection scheme, as well as testing DC systems associated with the scheme.
Single path	One communication path for the scheme.
Timing tests	Timing tests involve measuring processing, transmission and delay times as well as overall scheme operating times.

Appendix C. Consequence rating example

Note: This Appendix has been prepared to provide a general understanding of the processes contained in the Guidelines. These examples should not be relied upon as being indicative of the outcomes to be expected in real-life circumstances. To the extent that there is any inconsistency between the Guidelines and this Appendix, the Guidelines prevail in all circumstances. Below is a list of examples, which are then categorised and assessed to determine possible scheme requirements. In practice the final requirements will be determined by the NSP in consultation with AEMO as required.

The assessment examples are carried out considering only the basic functionality of the schemes, not back-up protection or duplication. This is because consequence rating assessments are envisaged as preceding and informing the final design of schemes under section 3.4 (including considerations such as back-up protection and duplication).

A1.1 Generation runback to prevent post-contingent transmission line overload

This assessment considers a generation runback scheme for a 200 MW generator, to prevent post-contingent overload of a transmission line following trip of a parallel circuit. The scheme is entirely topology based (operates based on circuit breaker status of monitored line).

Table 8 Generation runback scheme consequence rating assessment.

	Infrastructure	Market	Compliance	Highest rating
Spurious operation	**5 - Immaterial** Spurious runback is unlikely to lead to measurable infrastructure damage or affect.	**5 - Immaterial** Spurious runback is not expected to lead to loss of supply, unless this occurred during a period of low reserves.	**5 - Immaterial** Spurious runback is unlikely to lead to a non satisfactory operating state.	**5 - Immaterial**
Failure to operate	**3 - Moderate** The monitored transmission line would overload if runback failed to operate. The level of damage would depend on the size of the overload, and the time taken to remove the overload operationally. In this instance, it is estimated that the overload would be small, and the generator could be instructed to ramp down or be disconnected promptly. For other runback schemes it is plausible that infrastructure damage could fall under the Major or Catastrophic ratings.	**5 - Immaterial** No supply would be lost if runback failed to operate, however there may be subsequent impact on generation reserves.	**3 - Moderate** The monitored transmission line would overload if runback failed to operate. This would be a non satisfactory operating state on plant of localised area of a TNSP network.	**3 - Moderate**
Interaction with other schemes	**5 - Immaterial** Interaction with other schemes has potential to cause spurious operation. This is unlikely to lead to measurable infrastructure damage or affect.	**5 - Immaterial** Interaction with other schemes has potential to cause spurious operation, but is not expected to lead to loss of supply, unless this occurred during a period of low reserves.	**5 - Immaterial** Interaction with other schemes has potential to cause spurious operation. This is not likely to lead to a non-satisfactory operating condition.	**5 - Immaterial**

Overall Consequence rating	**3 - Moderate**

A1.2 Generation inter-trip due to low system strength following double circuit contingency

This assessment considers a new 200 MW wind farm seeking to join an existing inter-trip scheme, that trips up to 800 MW of generation following trip of a double circuit line. The trip of the double circuit line would cause the generation to have insufficient system strength to maintain stable operation. The scheme is entirely topology based (operates based on circuit breaker status of the monitored lines).

Table 9 Generation inter-trip scheme consequence rating assessment

	Infrastructure	Market	Compliance	Highest rating
Spurious operation	**5 - Immaterial** Spurious trip of generation is unlikely to lead to measurable infrastructure damage or affect.	**3 - Moderate** Spurious trip of generation could cause a large power swing, leading to islanding of a NEM region, and subsequent under frequency load shedding that is > 10% of demand in that region. Spurious operation may also have a subsequent impact on generation reserves.	**2 - Major** Spurious trip of generation could cause a large power swing, leading to islanding of a NEM region, and a non-satisfactory operating state existing on plant of a wide area of the local TNSP network (i.e. non-satisfactory frequency in the islanded region).	**2 - Major**
Failure to operate	**3 - Moderate** If generation fails to trip, low system strength could cause the generation to oscillate unstably. This could cause phenomena such as significant voltage fluctuations. These can lead to measurable damage and affect.	**3 - Moderate** If generation fails to trip, low system strength could cause the generation to oscillate unstably. This could cause phenomena such as significant voltage fluctuations, potentially causing subsequent generator disconnections and /or load disconnections >10% of demand in that region. The outcomes from sustained periods of system instability are highly variable, for other schemes it is plausible that loss of supply could fall under the Major or Catastrophic ratings.	**2 - Major** If generation fails to trip, low system strength could cause the generation to oscillate unstably. This could cause a non-satisfactory operating state to exist on plant of a wide area of the local TNSP network (i.e. non-satisfactory voltage fluctuations).	**2 - Major**
Interaction with other schemes	**5 - Immaterial** Interaction with other schemes could cause spurious tripping. Spurious trip of generation is unlikely to lead to measurable infrastructure damage or affect.	**3 - Moderate** Interaction with other schemes could cause spurious tripping. Spurious trip of generation could cause a large power swing, leading to islanding of a NEM region, and subsequent under frequency load shedding that is > 10% of demand in that region. It may also have subsequent impact on generation reserves.	**2 - Major** Interaction with other schemes could cause spurious tripping. Spurious trip of generation could cause a large power swing, leading to islanding of a NEM region, and a non-satisfactory operating state existing on plant of a wide area of the local TNSP network (i.e. non-satisfactory frequency in the islanded region).	**2 - Major**

Overall Consequence rating	**2 - Major**

A1.3 Wide area scheme to prevent system separation following multiple line trips

This assessment considers a scheme to prevent system separation following trip of two transmission lines in a four transmission line corridor. In the absence of the scheme, during periods of high corridor flow, trip of the first two lines could lead to angular separation across the remaining two lines, causing them to trip and separating the exporting and importing areas. To prevent this outcome, the scheme trips up to 600 MW of generation in the exporting area and up to 600 MW of load in the importing area. The scheme measures multiple analogue quantities (such as voltages magnitudes, voltage angles, power flows) to determine when to operate, rather than line/circuit breaker status.

Table 10 Wide area scheme consequence rating assessment

	Infrastructure	Market	Compliance	Highest rating
Spurious operation	**5 - Immaterial** Spurious operation of scheme is not likely to lead to measurable infrastructure damage or affect.	**3 - Moderate** Spurious operation of the scheme could trip all scheme load blocks, equating to > 10% of demand in the importing region.	**5 - Immaterial** Spurious operation of the scheme would not likely lead to a non-satisfactory operating state, but depends upon the scheme settings / thresholds and how much load / generation is armed at a particular time.	**2 - Major**
Failure to operate	**2 - Major** Failure of the scheme to operate could lead to angular separation and potentially pole-slipping of generators, with potential for equipment damage.	**1 - Catastrophic** If the scheme fails to operate it could lead to system separation, with loss of > 50% of demand in a NEM region (such as a black system event in the islanded region or sub-region).	**2 - Major** If the scheme fails to operate it could lead to system separation, leading to a non-satisfactory operating state existing on plant of a wide area of the local TNSP network (i.e. non-satisfactory frequency in the islanded region).	**1 - Catastrophic**
Interaction with other schemes	**5 - Immaterial** Interaction with other schemes could cause spurious operation. Spurious operation of scheme is not likely to lead to measurable infrastructure damage or affect.	**3 - Moderate** Interaction with other schemes could cause spurious operation. Spurious operation of the scheme could trip all scheme load blocks, equating to > 10% of demand in the region.	**5 - Immaterial** Interaction with other schemes could cause spurious operation. Spurious operation of the scheme would not likely lead to a non-satisfactory operating state, but depends upon the scheme settings / thresholds and how much load / generation is armed at a particular time.	**2 - Major**

Overall Consequence rating	**1 - Catastrophic**