



**WECC**

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## **Remedial Action Scheme Design Guide**

Relay Work Group

Remedial Action Scheme Review Subcommittee

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### 1.0 Introduction

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Remedial Action Schemes (RAS), also known as Special Protection Systems (SPS) or System Integrity Protection Schemes (SIPS), are widely used to provide automatic mitigation of performance violations on power systems other than detecting Faults on BES Elements and isolating the faulted Elements. The terms SPS and RAS are often used interchangeably, but, historically, WECC has used the term RAS. NERC adopted the RAS terminology in the 2015 edition of its Glossary<sup>1</sup> and in PRC-012-2 and other standards. SPS is no longer the NERC-preferred term for these schemes. IEEE generally uses SIPS<sup>2</sup>, which covers a wider range of schemes, such as distributed undervoltage load shedding (UVLS) and underfrequency load shedding (UFLS), that are not included in the NERC terminology.

Economic incentives and other factors have led to increased electric transmission system usage, power transfers, and changes in historic usage patterns, both among regions and within individual utilities. New transmission construction has often lagged behind these changes, resulting in lower operating margins. RAS are generally applied to solve single- and credible multiple-contingency problems. RAS are automatic schemes that apply mitigation actions for sensed contingencies without operator intervention. These schemes have become more common primarily because they are usually less costly and quicker to permit, design, and build than other alternatives such as major transmission lines and power plants.

RAS in the Western Interconnection supplement ordinary protection and control devices (fault protection, reclosing, AVR, PSS, governors, AGC, etc.) to prevent violations of the NERC Reliability Standards, such as TPL-001. RAS sense abnormal system conditions and take pre-determined or pre-designed action to prevent those conditions from escalating into major system disturbances. RAS actions may minimize equipment damage, cascading outages, uncontrolled loss of generation, and interruptions of customer electric service.

Given the complexity of RAS design, the Relay Work Group (RWG) recommends that users of this guide familiarize themselves with the complete document before embarking on any design process. This guide references several other documents that will affect the design process for any RAS. Since this is a guide, no requirements should be implied; the RWG is presenting utility best practices and recommendations.

Requirements for distributed UFLS and distributed UVLS schemes are not addressed in detail here. They are addressed separately by several NERC and WECC documents. These documents provide satisfactory guidance on these subjects. Therefore, distributed UFLS and UVLS schemes designed in

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<sup>1</sup> See the NERC Glossary of Terms for the Remedial Action Scheme definition.

<sup>2</sup> C37.250, IEEE Guide for Engineering, Implementation, and Management of System Integrity Protection Schemes, 2020



compliance with these NERC and WECC requirements have not normally required further review by WECC as RAS. Centrally controlled UFLS and UVLS schemes are typically RAS and should follow the guidance provided in this document.

### 1.1 Problem Recognition and Definition

Problem recognition and detection methods center on system planning studies on a scale ranging from individual Transmission Planners to interconnection-wide. Typically planning studies conducted to comply with TPL-001 are used to detect system problems, determine the need for a RAS, and the characteristics needed to mitigate the problems.

### 1.2 FERC-Approved RAS Definition

There are a set of earlier NERC Standards relating to RAS; these are PRC-012-0 through PRC-017-0 and PRC-012-1 through PRC-014-1. FERC determined that three of the existing RAS Standards, PRC-012-0 through PRC-014-0, were “fill in the blank” and, therefore, not enforceable. NERC formed a Standard Drafting Team to create a new Standard correcting the deficiency. The result is the new RAS Standard PRC-012-2. (The -1 versions of these standards only changed the terminology from SPS to RAS.)

As part of the Standard development process for PRC-012-2, NERC determined that a more concise definition of what constitutes a RAS was necessary. The prior SPS/RAS definition lacked clarity and specificity to allow entities to identify schemes that may or may not be RAS. This created confusion and inconsistent application of Standards relating to RAS. The FERC-approved RAS definition, effective April 1, 2017, is:

A scheme designed to detect predetermined System conditions and automatically take corrective actions that may include, but are not limited to, adjusting or tripping generation (MW and Mvar), tripping load, or reconfiguring a System(s). RAS accomplish objectives such as:

- Meet requirements identified in the NERC Reliability Standards;
- Maintain Bulk Electric System (BES) stability;
- Maintain acceptable BES voltages;
- Maintain acceptable BES power flows;
- Limit the impact of Cascading or extreme events.

The following do not individually constitute a RAS:

- a. Protection Systems installed for the purpose of detecting Faults on BES Elements and isolating the faulted Elements
- b. Schemes for automatic underfrequency load shedding (UFLS) and automatic undervoltage load shedding (UVLS) comprised of only distributed relays
- c. Out-of-step tripping and power swing blocking
- d. Automatic reclosing schemes



- e. Schemes applied on an Element for non-Fault conditions, such as, but not limited to, generator loss-of-field, transformer top-oil temperature, overvoltage, or overload to protect the Element against damage by removing it from service
- f. Controllers that switch or regulate one or more of the following: series or shunt reactive devices, flexible alternating current transmission system (FACTS) devices, phase-shifting transformers, variable-frequency transformers, or tap-changing transformers; and that are located at and monitor quantities solely at the same station as the Element being switched or regulated
- g. FACTS controllers that remotely switch static shunt reactive devices located at other stations to regulate the output of a single FACTS device
- h. Schemes or controllers that remotely switch shunt reactors and shunt capacitors for voltage regulation that would otherwise be manually switched
- i. Schemes that automatically de-energize a line for a non-Fault operation when one end of the line is open
- j. Schemes that provide anti-islanding protection (e.g., protect load from effects of being isolated with generation that may not be capable of maintaining acceptable frequency and voltage)
- k. Automatic sequences that proceed when manually initiated solely by a System Operator
- l. Modulation of HVdc or FACTS via supplementary controls, such as angle damping or frequency damping applied to damp local or inter-area oscillations
- m. Sub-synchronous resonance (SSR) protection schemes that directly detect sub-synchronous quantities (e.g., currents or torsional oscillations)
- n. Generator controls such as, but not limited to, automatic generation control (AGC), generation excitation [e.g., automatic voltage regulation (AVR) and power system stabilizers (PSS)], fast valving, and speed governing

The new RAS Standard PRC-012-2 also introduced the term RAS-entity: the Transmission Owner, Generator Owner, or Distribution Provider that owns all or part of a RAS, asserting that all owners of RAS components are RAS-entities. NERC chose this term to keep all entities accountable for coordination and cooperation with RAS to enhance reliability.

All NERC-regulated entities must apply this definition to schemes in their operating area that qualify as RAS and have applicability to the numerous RAS-related Requirements in the NERC Standards.

## 2.0 Common RAS Control Principles

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RAS detect predetermined System conditions and automatically take corrective actions. These actions are achieved via simple control principles (though application may be quite complex), typically one or more of the following:



- Event-based,
- Parameter-based,
- Response-based, or
- A combination of the above.

Event-based schemes directly detect outages and fault events and initiate actions such as generator/load tripping to mitigate the event's impact fully or partially. This open-loop type of control is commonly used for preventing system instabilities when necessary remedial actions need to be applied as quickly as possible.

Parameter-based schemes measure variables for which a significant change confirms the occurrence of a critical event. This is also a form of open-loop control but with indirect event detection. The indirect method is mainly used to detect remote switching of breakers (e.g., an opposite end of a line) and significant sudden changes which can cause instabilities but may not be readily detected directly. To timely execute remedial action, the measured variables may include power, angles, etc., or their derivatives.

Most event- and parameter-based schemes are triggered by a combination of events and parameters. These schemes initiate planned actions based on studies of predefined system contingencies for a variety of conditions.

Response-based schemes monitor system response during disturbances and incorporate a closed-loop process to react to actual system conditions. Response-based scheme action may be more finely calibrated to the magnitude of the disturbance, but usually is not fast enough to prevent instabilities following severe disturbances. Some equipment unloading schemes could be interpreted as response-based, closed-loop schemes. A response-based scheme can be used when a gradual (e.g., step-by-step) increase of remedial action is acceptable.

### 3.0 Typical RAS Features

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Critical details of the RAS design and operating characteristics must be determined through appropriate studies. Among the more important recommendations and conclusions of these studies might be:

- **Arming Criteria:** Critical system conditions for which a stepwise RAS should be ready to act when required. Different arming criteria may apply to different contingencies or System conditions.
- **Initiating Conditions:** The critical contingencies to initiate action if the scheme is armed. Parameter-based RAS detect changes in critical system conditions rather than directly detecting specific conditions.
- **Action Taken:** The minimum remedial action required for each contingency (when armed) and the maximum acceptable remedial action for each contingency (when pertinent).



- Time Requirements, Time Budget, or Allowable Time: The maximum time allowable for the remedial action to be accomplished.
- Negative Reliability Impacts: Identification of any negative impacts from activation of RAS must be considered in the initial design of the RAS. These impacts could include activation of UFLS programs in the interconnection as a whole when generation-dropping RAS operate, etc.

**Critical system conditions** that influence arming are often identified by one or more of the following:

- Generation patterns,
- Transmission line loadings,
- Load patterns,
- Reactive power reserves,
- System response as determined from the data provided by wide-area measurement systems, or
- Other unsustainable conditions identified by studies of system characteristics.

For example, during lightly loaded system conditions, a transmission line outage may not cause any reliability criteria violations, but during heavier loads, the same outage may result in generator instability or overloads on remaining facilities.

Automatic single-phase or three-phase reclosing following temporary faults during stressed operating conditions may avoid the need to take remedial action. RAS action may still be required if reclosing is unsuccessful.

The RAS is designed to mitigate specific effects of **critical contingencies** that initiate the actual system problems. There may be a single critical outage or there may be several critical single contingency outages for which remedial action is needed. There may also be credible double or other multiple contingencies for which remedial action is needed. Each critical contingency may require a separate arming level and different remedial actions.

Various possible remedial actions are usually available to improve system performance. These may include but are not limited to:

- Islanding or other line tripping,
- Generator tripping,
- Generator runback
- Load tripping (direct, underfrequency, undervoltage),
- Braking resistors,
- Static VAR control units,
- Capacitor switching, reactor switching, or both.

The minimum remedial action required is determined through studies that identify the boundary between acceptable and unacceptable System performance. Remedial action in addition to this minimum level often can result in further system performance improvements. At some higher action



level, System performance standards may again be violated if System response approaches another part of the boundary (e.g., high voltage due to extra load shedding). However, some extra remedial action (safety margin) should be applied to ensure that at least the minimum action will still occur even for the worst-case credible scheme failure (typically a single RAS component). While actions above the necessary “safety margin” do not create new violations, they may make the scheme costlier and more complex, as well as result in a larger impact to customers (e.g., reduction of generating reserve, shed more load).

The maximum time allowable to act will change with the type of problem for which the RAS is a solution. Short-term angular and voltage stability problems typically require the fastest response, as fast as a few cycles, but usually less than one second. Actions to mitigate steady-state stability and slow voltage collapse problems may allow several seconds. Thermal overload problems could allow up to several minutes before action is required.

Often sensing, logic processing, and corrective action will take place at different sites. A RAS senses System conditions, communicates to a logic processor that is enabled with the appropriate arming based on pre-determined corrective actions at each arming level and for each contingency, and initiates appropriate actions, usually through communications links among remote sites. In this common configuration, RAS are critically dependent on high-speed telecommunications, condition-sensing, arming, logic processing, and action equipment.

Often System problems and their solutions through RAS involve more than a single RAS-entity. The resulting RAS will require negotiations among the RAS-entities (including technical specialists needed to implement the proposed RAS) identifying the conditions to be monitored, scheme logic, logic processing, and the actions to be taken. The NERC TPL-001 provides the starting point to evaluate System performance. These performance requirements must be met by entities within the Western Interconnection. Detailed scheme design can begin after the discussions among parties reach a consensus.

### 4.0 Philosophy and General Design Criteria

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In general, the design philosophy appropriate for a RAS is that all System performance criteria will still be met, even following a single device or component failure within the RAS. As with other protection systems, this design objective is often met with a fully redundant design. A fully redundant design will avoid the possibility of a single component failure that would jeopardize successful operation of the RAS. However, as described below, a fully redundant design is not always required to meet the performance criteria.

RAS are unique and customized assemblages of protection and control equipment that vary in complexity and impact on the reliability of the BES. In recognition of these differences, RAS can be designated by the reviewing Reliability Coordinator (RC) under PRC-012-2 as “limited impact.” If a



RAS cannot, by inadvertent operation or failure to operate, cause or contribute to BES Cascading, uncontrolled separation, angular instability, voltage instability, voltage collapse, or unacceptably damped oscillations, it may be considered to have limited impact on the System. A RAS implemented before the effective date of PRC-012-2 that has been through the WECC Remedial Action Scheme review is recognized as limited impact before the next evaluation by the relevant Planning Coordinator. When appropriate, the RAS-entity for new or functionally modified RAS will claim limited impact status for its RAS, which will be confirmed (or not) as limited impact by the RC during the RAS review process.

A RAS that creates a large imbalance of generation to load (generation-dropping RAS) has unique criteria that need to be addressed in the design. The designers of these types of RAS need to be aware of the reliability impacts in the longer-term periods than normally studied for transient analysis. Regarding interconnection frequency performance that occurs in the 5- to 10-second period after the event occurs, the Western Interconnection is designed to be reliably operated with consideration of specific contingencies. Generation-dropping RAS design needs to avoid initiating the Western Interconnections Underfrequency Load Shedding programs when the RAS operates. A generation-dropping RAS that can be activated in the Western Interconnection should never exceed the magnitude of the Western Interconnection's Resource Loss Protection Criteria ([RLPC](#)) unless an amount of firm load is shed that corresponds with the exceeded amount, as described in BAL-003. The NERC Frequency Response Annual Analysis can be found [here](#).

### 4.1 Logic

The operating requirements for any RAS are derived from the System simulation studies that identify the problem (e.g., loss of any of several specific lines during heavy export conditions would initiate out-of-step conditions on a remaining intertie), appropriate actions to mitigate the problem (e.g., generation tripping in the area that had been exporting before the outage), and the maximum time available to act.

Documentation of this scheme logic will direct the detailed implementation design, aid in necessary reviews, and assist personnel when installing and testing the scheme. The logic documentation may be a written description, equations, flow charts, matrix logic tables, timing tables, logic diagrams, charts etc., or a combination of formats. The documentation will also include all scheme inputs and outputs.

### 4.2 Hardware

The RWG recommends that hardware used to implement a RAS meet the same standards that apply to Protection Systems, including but not limited to

- IEEE Power System Relaying Committee, "IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems Associated with Electric Power Apparatus," IEEE/ANSI Standard C37.90.1-2012, IEEE Standard C37-90-2005.



- IEEE Power System Relaying Committee, “IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus,” IEEE/ANSI Standard C37.90-2005.
- IEEE Power System Relaying Committee, “IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers,” ANSI/IEEE Standard C37.90.2-2004.

Technology advances have given the designer many solution options. The designer will often have a choice of several platforms to build the RAS—multi-function or single-function relays, digital computer, programmable logic controller, etc.

### 4.3 Arming

Some RAS do not depend on a traditional arming concept. These systems are characterized by fast computations and detect critical changes in system conditions rather than specific pre-disturbance levels or status. In this sense, they are always “armed” and ready to initiate action when they detect the critical disturbance.

However, many RAS monitor load, generation levels, voltage, frequency, breaker status, or other quantities or devices that are critical to identifying the onset of the system problem which RAS are designed to mitigate. Analog quantities are the most common functions used to identify when a scheme should be armed. If analog quantities such as line power flows are the appropriate level detection criteria, the specific quantities may be monitored by transducers, microprocessor-based relays, communications processors, analog cards within programmable logic controllers, or other devices.

Often analog quantities or status at more than one location are required to determine when a scheme should be armed. Use of SCADA and an energy management system (EMS) computer to collect the data and perform the calculations is a common application. Programmable logic controllers, microprocessor-based relays, and other intelligent electronic devices (IED) are also commonly used to perform these functions.

Both EMS computer and SCADA or the scheme logic processor (locally or remotely) are commonly used for scheme arming at logic processing and action locations. Actual scheme arming may be done either automatically or manually, depending on the philosophy of the entity and the specific characteristics of the scheme. If arming is automatic, the dispatcher should at least be provided with indication of the arming status.

If arming is manual, then written procedures, the EMS, or logic processor should provide the dispatcher with a recommendation on when the scheme should be armed as well as arming status. For EMS-calculated manual arming, the RAS designer can consider using a lookup table or similar document that a dispatcher can use as a manual backup. If there are choices on what specific actions should be armed (e.g., trip loads at either station A or station B), the scheme will make an initial choice,



which the dispatcher can override. Some utilities include the ability to arm a scheme with a local switch from logic processing or at action locations. This is acceptable, though most often used when the arming location is staffed around the clock, such as at a power plant or staffed substation or the status of the switch is brought to a continuously staffed location.

### 4.4 Detection and Initiating Devices

Detection and initiating devices must be designed to emphasize security. The following discussion identifies several types of devices that have been used as disturbance detectors:

- Line open status (event detectors),
- Protective relay inputs and outputs (event and parameter detectors),
- Transducer and IED (analog) inputs (parameter and response detectors),
- Rate of change (parameter and response detectors).

Several methods to determine line open status or contingency status are in common use, often in combination:

- Auxiliary switch contacts from circuit breakers and disconnect switches (52, 89),
- Undercurrent detection (a low level indicates an outage),
- Protective relay trip outputs,
- Breaker trip bus monitoring, and
- Other detectors such as angle, voltage, power, frequency, rate of change of these, out of step, etc.

Circuit breaker or disconnect switch auxiliary contacts are often part of the outage detection input to a logic circuit. Observe the following precautions when using these contacts:

- Use of auxiliary relays as contact multipliers for critical scheme detection 52b/89b contacts should generally be avoided, but, when necessary, must be done very carefully, especially if these contacts are used as the only or primary line outage detection method. Make sure that loss of the auxiliary supply voltage does not provide false indications to the RAS. Where possible, use the breaker/switch contact directly for RAS outage detection. Whether directly or through auxiliary relays, separate contacts should be used for inputs to redundant schemes (see discussion below).
- When a circuit breaker is out of service, disconnect switches open, and the breaker subsequently closed, the 52b switch is no longer a reliable indicator of the availability of the breaker as part of the RAS. The scheme logic must include accommodation for this configuration. Commonly used methods include auxiliary contacts on the disconnect switches (89b) or a separate “maintenance,” “out of service,” or “local/remote” (43) control switch to provide the proper indications.



- Logic must recognize line disconnect switches where used. If the line switches can be operated remotely or automatically, the detection logic must be automatic.
- Detection logic must be able to detect a line being open at either end (monitor both ends of the line).
- Inadvertent bypassing of the 52b switches by personnel operating the maintenance/out-of-service switch or failure of a complicated automatic scheme can cause a false RAS operation. Supervision of the 52b logic by undercurrent or underpower can prevent such false operations.
- Where microprocessor-based devices are used, consider the use of integrated pole open logic. The user must understand the device internal logic to ensure appropriate security and dependability.
- Auxiliary switches monitoring disconnect switch position (89b) optimally should follow actual switch blade position rather than just the operating mechanism. Operation of the mechanism with the switch de-coupled could cause false operations similar to inadvertent bypassing of breaker 52b contacts discussed above. Otherwise, the design will need to accommodate the de-coupled indications.
- If manual transfer or maintenance switches are used in parallel with 52b breaker auxiliary contacts, the manual switch position should be monitored by the local substation annunciator, sequence of events recorder, or SCADA to reduce the possibility of leaving the switch in the wrong position when the breaker is returned to service.

Undercurrent sensing may be used for outage detection. Loss of transmission line power flow is occasionally used as a variation of undercurrent detection. Current detection may have the advantage of being able to detect an open terminal at the far end of the line as well as locally without a separate communication channel. Undercurrent detection is independent of auxiliary and maintenance switch contacts. This detection method requires the following precautions:

- The undercurrent level setting must be above the level of line charging current (including the effects of any fixed or switched shunt reactors) and corona losses if sensing at one end, but below minimum line flows when both ends of the line are in service.
- The minimum current may be quite small for short lines, if a high percentage of shunt compensation is used, if power flow may reverse direction, or if the line is operated at a lower voltage. This can make outage detection via undercurrent sensing alone problematic.
- Detection logic must be defeated when the undercurrent relay is out of service for maintenance, testing, or other purposes.

Protective relay trip outputs or breaker trip bus monitoring is often used when scheme operating time requirements are very short. The timing advantage arises because the logic signal initiation occurs when the relay detects the requirement to trip the Element or the circuit breaker trip bus is energized, ahead of the operating time of the breaker mechanism and auxiliary switches or interruption of the circuit breaker current. Depending primarily on the relay and rated voltage and design of the breaker,



this may save one to five cycles (17-80 milliseconds) in overall scheme operation. This detection method requires the following precautions:

- For relay trips, separate output contacts should be used to provide inputs to the RAS logic from the contacts used to trip the Element.
- For breaker trips initiated by a protective relay or control switch, a separate contact output or internal trip equation of the relay or control switch may be used to detect line open status.
- For current operated devices, breaker DC trip current should be monitored using a trip-indicating relay or similar device with an operating current value appropriate for the specific circuit breaker. Since the trip-indicating relay is in series with the trip coil, and may not operate for open trip coil, trip coil monitoring is appropriate to identify failures before failure-to-trip the breaker. The trip coil failure alarm should be brought into the EMS.
- For voltage-operated devices monitoring the breaker trip bus, pickup level of the device and resistance must be carefully considered to ensure that it is not inadvertently operated by “sneak circuits” such as the red indicating light. Due to this complication, a current-operated detector is usually preferred over a voltage-operated detector.
- For breakers with two trip coils, both coils should be monitored.
- For most designs, undercurrent or 52b status detection may be required in addition to relay, current or voltage schemes for breaker trip bus monitoring because the trip logic signal only monitors relay trip contact or the DC current flowing through the breaker trip coil (or the trip bus voltage). Once the breaker opens, the coil current falls to zero and a separate detection method must be used to recognize breaker status.

**Voltage, power, frequency, or out-of-step relays** may be used when those functions provide reliable and secure methods of detecting the condition being monitored for the RAS. Precautions often require more effort to ensure reliable operation than when other detection methods are used.

- Power flow is often used to make RAS arming decisions, but is also occasionally used for triggering decisions, especially for schemes that monitor for overloaded Elements.
- Voltage sensing (where needed) should monitor all three phases at the critical transmission level.
- Rate of change of voltage, current, power or frequency may be used, but with extreme caution in determining the settings required to distinguish between local faults, switching, or System problems which should initiate the RAS.
- Out-of-step tripping (OST) may be used to interrupt pending instability. Studies must be done, such as those described in NERC standard PRC-026-1 Application Guidelines, to ensure that the settings will not result in tripping for stable swings and must also address undesired tripping on out-of-step conditions outside of the given component. These relays are usually applied when there is enough time to trip “on the way out” of the swing. If time is critical and tripping must be “on the way in,” then transient recovery voltage across the tripping circuit breaker(s)



must be evaluated to prevent re-strikes. Tripping “on the way in” requires a more precise setting to prevent trips on stable swings and may require a higher breaker rating.

- Power swing blocking (PSB) may supervise relay distance or overcurrent elements during system swings if studies show that the impedance trajectory can penetrate the reach of the relays. The recommended application combines blocking all relay impedance zones at locations where OST is not desired and allows tripping using the OST function available in modern relays for unstable power swings at locations determined by system studies.

### 4.5 Logic Processing

All RAS require some form of logic processing to determine the action to take when the scheme is triggered. Required actions are always scheme dependent. Different actions may be required at different arming levels or for different contingencies. Scheme logic may be achievable by something as simple as wiring a few auxiliary relay contacts or by much more complex logic processing. The RWG recommends the designer choose a design to maximize dependability and security, minimize complexity, provide for safe scheme testing, and allow for easy future modifications. If multiple RAS are contained in the same logic processor, consideration should be given to the consequences of a total failure and the possibility of splitting RAS among several logic processors.

Platforms that have been used reliably and successfully include programmable logic controllers (PLC), computers, multi-function programmable protective relays, remote terminal units (RTU), and logic processors. Single-function relays have been used historically to implement RAS, but this approach is now less common except for very simple new installations or minor additions to existing schemes.

### 4.6 Communications Channels

Communication channels used for sending and receiving logic or other information between local and remote sites and/or transfer trip devices must meet at least the same criteria as for other Protective Relaying communication channels. These requirements are outlined in Communications Systems Performance Guide for Electric Protection Systems and Guidelines for the Design of Critical Communications Circuits, both documents are available on the WECC web site.

The scheme logic should be designed so that loss of the channel, noise, or other channel failure will not result in a false operation of the scheme. It is highly desirable that the channel equipment and communications media (power line carrier, microwave, optical fiber, etc.) be owned and maintained by the RAS owner, or perhaps leased from another WECC member utility familiar with the necessary reliability requirements. All channels and channel equipment should be monitored and alarmed to the dispatch center so that timely diagnostic and repair action will take place upon failure.

Leased telephone circuits or pilot wire circuits on power system structures are likely to lead to unreliable operations. Such channels should only be used when no other communications media are



available. Automatic channel testing and continuous monitoring are required if telephone leased lines are used.

To maintain RAS reliability, communication channels should be well labeled and identified so that the personnel working on the channel can readily identify the proper circuit. Channels between entities should be identified with a common name at all terminals.

### 4.7 Cyber Security

The NERC family of Critical Infrastructure Protection (CIP) Standards continues to undergo development and modification. Version 5 became effective on July 1, 2016, and development is ongoing for future versions. Each RAS must be designed in accordance with each entity's CIP program and processes created to address the Requirements of the CIP Standards.

### 4.8 Transfer Trip Equipment

Transfer trip equipment for RAS applications should meet the same hardware design and reliability standards as for other communication-aided Protective Relaying applications. Commonly used types of transfer trip equipment include frequency shift key (FSK) audio tone, frequency shift (FS) carrier, peer-to-peer digital, etc. Operating time must be compatible with the requirements for the specific RAS. Security against false trips is often accomplished by the same methods as used in direct transfer tripping applications, e.g., guard and trip frequencies shift in opposite directions for FSK systems. Additional criteria can be found in the references.

### 4.9 Test Switches

The historical NERC/WECC Planning Standards that considered test switches within RAS are similar to those for Protection Systems. The 1997 NERC and 2002 WECC RAS standards included the following guidance, which is still a best practice today:

- G5. SPS [RAS] should be designed to minimize the likelihood of personnel error such as incorrect operation and inadvertent disabling. Test switches should be used to eliminate the necessity for removing or disconnecting wires during testing.
- G6. The design of SPS [RAS] both in terms of circuitry and physical arrangement should facilitate periodic testing and maintenance. Test facilities and procedures should be designed such that they do not compromise the independence of redundant SPS [RAS] groups.

Test and cutout switches for initiation, logic processing, tone communications, and action circuits should be designed as an integral part of the RAS at all locations where any of these functions occur. Switches should be readily accessible to operating personnel for maintenance and test purposes using a written procedure. The switches should be labeled with a name that is short, precise, and directly



related to the remedial action scheme function. Common nomenclature should be used at all locations for a RAS involving more than one entity.

### 4.10 Redundancy

Redundancy is an effective design philosophy to eliminate single component failures that could prevent a RAS from operating. RAS redundancy requirements are similar to the requirements for Protection Systems. Redundancy is intended to allow removal of part or all of one scheme due to a failure, or to allow for maintenance on a scheme, while providing full scheme capability with a functionally equivalent and separate scheme. Redundancy requirements should include all aspects of the scheme design including detection, arming, alarms, power supplies, telecommunication systems, logic controllers, relays, and action circuits.

As discussed previously, a “limited impact” RAS determined in PRC-012-2, cannot, by inadvertent operation or failure to operate, cause or contribute to BES Cascading, uncontrolled separation, angular instability, voltage instability, voltage collapse, or unacceptably damped oscillations. With this qualification, redundancy may not be required if required system performance is achieved. However, redundancy should be considered as a utility best practice for RAS with “limited impact” on the System.

The PRC-012-2 Standard does not specifically require redundancy but focuses on meeting the performance requirements for the BES, such as those documented in TPL-001. However, each RAS- entity must demonstrate in provisions that a single component failure within a RAS must not prevent the interconnected transmission system from meeting the system performance requirements (PRC-012-2 R4). Most often, redundancy is perceived to be the most straightforward and economical means to meet the performance requirements for a single component failure. It is the designer’s / owner’s responsibility to ensure that failure of non-redundant equipment for all credible scheme failures will still result in system performance that is within the NERC Standard<sup>1</sup>.

Single component malfunctions may cause inadvertent RAS operation, which decreases the security of the Bulk Electric System. As described in PRC-012-2, Requirement R4 clarifies that the inadvertent operation to be considered is only that caused by the malfunction of a single RAS component. This allows security features to be designed into the RAS such that inadvertent operation due to a single component malfunction is prevented. Otherwise, consistent with PRC-012-2 Attachment 1, Part II.6, the RAS should be designed so that its whole or partial inadvertent operation due to a single component malfunction satisfies the System performance requirements for the same Contingency for which the RAS was designed

For events without performance requirements, i.e., extreme events, the minimum performance requirements following an inadvertent operation are those common to all planning events P0-P7 listed in TPL-001.



- The BES shall remain stable.
- Cascading shall not occur.
- Applicable Facility Ratings shall not be exceeded.
- BES voltages shall be within post-Contingency voltage limits and post-Contingency voltage deviation limits as established by the Transmission Planner and the Planning Coordinator.
- Transient voltage responses shall be within acceptable limits as established by the Transmission Planner and the Planning Coordinator.

Acceptable alternative to full redundancy, a non-redundant RAS design is recommended to meet the following performance criterion:

- Provide adequate backup, such as over-tripping in a load shedding RAS when communication channels to the load shed sites are not redundant. Over-tripping should not expand the problem.
- Monitor and alarm all critical RAS elements—especially ones where single component failure can defeat the RAS functionality and ensure operational procedures are in place to initiate corrective actions for alarms.
- Depending on the scheme design and objectives, the following may also be necessary:
  - Determine if the System can be adjusted so that the RAS need not be armed, and operation is not required for the critical outage(s).
  - Provide adequate dispatcher training and operational procedures to immediately adjust the System so that operation of available parts of the RAS will still meet the System performance requirements of the Standards if any of these critical alarms occur, e.g., arm alternate load shed sites.

Utility practices allow a few parts of Protection Systems to be non-redundant regardless of the criteria above. A partial list includes:

- Station battery. The Standards require only that separately fused DC control circuits be used to supply otherwise-redundant protective devices and that the battery/charger system be alarmed to indicate failures, including an open battery circuit. It is becoming more common that utilities use separate batteries and chargers, especially at higher system voltages and when circuit breakers include two trip coils, but this is not required by the Standards.
- Potential sensing devices (PTs, CCVTs, optical). It is acceptable that voltage sensing be provided from separate secondary windings of voltage sensing devices.
- Breaker failure protection is specifically exempted from a redundancy requirement. See the discussion below.
- Microwave antennas, towers, and waveguides.

Good utility industry practice and the Standards encourage fully redundant RAS. However, the minimum requirement for all systems is to provide adequate backup protection, the operation of which



will not result in violating the performance requirements. A simple example of a non-redundant protection scheme with adequate backup is a distribution feeder protected by separate electro-mechanical phase and ground relays. If any single relay fails or is out of service, at least one other relay can still sense any possible feeder fault and initiate a breaker trip. A RAS example would overtrip load if redundant communications facilities are not provided to the different load shed locations.

Acceptable conditions to avoid full redundancy might include emergency operating orders to reduce flows on the critical system elements so that the RAS would not need to be armed, resulting in (dispatcher modified) System conditions that no longer require RAS operation for the critical contingency. Depending on the anticipated severity, frequency, and duration of System conditions that require dispatcher curtailments, the economics of the situation will often encourage full scheme redundancy.

RAS logic processing will usually need to be redundant to assure meeting minimum performance requirements. The scheme designer must consider the power system effects if the controller arming or actions do not match. This could result in either an unnecessary scheme operation or failure to operate by one of the systems. Redundant logic processors should at least provide a “mismatch” alarm and the System operator should be provided with standing orders describing appropriate subsequent procedures.

Implementing a centralized design philosophy typically would have multiple RAS share status monitors and action devices. Such schemes need to pay close attention to the single component failure analysis results to be certain that System performance requirements can be met for all RAS that share devices.

For large and complex RAS, economic scheduling issues are usually so important and the consequences of scheme misoperations are so unacceptable that full scheme redundancy is the rule. For example, some schemes use a logic processing design for the first scheme (RAS A) that is a triply redundant set of programmable logic controllers arranged in a two-of-three voting scheme and the redundant scheme (RAS B) is a second triply redundant set of programmable logic controllers arranged in a separate two-of-three voting scheme. Arming information based on line flows is provided from A and B sets of transducers or IEDs. The A and B schemes have separate 52b and trip coil sensing at both ends of the critical line(s). Requirements for redundancy in communication circuits is defined in the WECC document, Communications Systems Performance Guide for Electric Protection Systems.

Some utilities are willing to continue otherwise normal operations with a single fully functional RAS or protection scheme available during an outage of a redundant scheme. Other utilities are unwilling to operate without a redundant RAS (or protection) available for longer than would be required to switch a third “standby” system into service, or at reduced facility ratings. Either operating philosophy is allowed.



### 4.11 Breaker Failure

Failure of a circuit breaker to operate when called upon to operate by the RAS, even when equipped with dual trip coils, is considered a credible failure. This had been clearly stated in the FAC-010 and FAC-011 Regional Differences for WECC before those NERC standards were retired:

**1.1.4** The failure of a circuit breaker associated with a Special Protection System [RAS] to operate when required following: the loss of any element without a Fault; or a permanent phase to ground Fault, with Normal Clearing, on any transmission circuit, transformer, or bus section.

The drafting team WECC-0113 recommended that similar language be incorporated in another appropriate standard as a regional variance, if necessary. This has not yet occurred.

NPCC describes similar requirements for its Type I RAS in its Directory 7 as follows:

RAS shall include breaker failure protection for each circuit breaker whose operation is critical to the adequacy of the action taken by the [RAS] with due regard to the power system conditions this [RAS] is required to detect.

Following are some common and acceptable methods to remediate such a failure:

- Over-operate RAS action, e.g., trip extra generation equivalent to the largest generator or generation site which may fail to trip.
  - Initiate breaker failure protection. Traditional breaker failure operation, as a second contingency, would often be problematic as a RAS mitigation action. Traditional breaker failure scheme purpose is to clear faults by isolating faulted equipment. Breaker failure schemes also do not address possible failure of a RAS associated breaker to close.
- The breaker failure scheme can also add significantly to the time for a RAS to operate, which may not be acceptable for a high-speed transient stability RAS.

If traditional breaker failure scheme operation would not result in meeting the RAS system performance requirements, the RAS designer should identify some alternate action that would allow System performance requirements to be met.

NPCC identifies similar options for breaker failure protection:

- A design which recognizes that the breaker has not achieved or will not achieve the intended function required by the [RAS] and which takes independent action to achieve that function. This provision need not be duplicated and can be combined with conventional breaker failure schemes if appropriate.
- Over-arming the [RAS] such that adequate action is taken even if a single breaker fails.
- The redundancy afforded by actions taken by other independent schemes or devices.



The scheme designer is not limited to these methods to address failure of a breaker to operate. However, it should be shown that failure of a breaker to trip (or close) will still result in acceptable System performance.

### 4.12 Communication Circuit Redundancy

Communication circuits are designed to meet a minimum availability required for a given level of protection as defined in WECC guide Communications Systems Performance Guide for Electric Protection Systems and calculated with the WECC Communication Circuit Availability Calculations guide. Redundancy and diversity are methods to achieve the required circuit availability and designed such that there are no “credible” single points of failure in the system.

Credible sources of failure generally **include** the electronic and mechanical systems such as radios, switches, DC backups, and batteries. Non-credible sources generally include physical infrastructure including the communication tower, waveguides, and antennas under the assumption of proper maintenance of the physical infrastructure.

Redundant and diverse communication channels can be achieved in a variety of methods depending on requirements and site conditions. These may include:

- Space-diverse or frequency-diverse microwave systems on a single communications site
- Geographically diverse microwave paths from separate communication sites
- Separate fiber paths
- Separate communication technologies such as a combination of a microwave and a fiber path

Two power line carrier systems coupled to two or three phases of the line.

The telecommunication system designer should evaluate the different methods of implementing redundant and diverse routing given the unique conditions between the communication sites. Separate fiber paths are not financially realistic in some locations, and separate geographic paths may be limited by environmental conditions. Leased communication circuits may be used to achieve diversity but are not as preferable as a utility owned circuit.

### 4.13 Monitoring and Alarms

The Standards require adequate monitoring of all Protection Systems (including RAS) so that Misoperations and failures can be identified, and maintenance personnel can be dispatched in a timely manner to remove failed equipment from service and make repairs. It is the responsibility of the RAS entity to ensure that monitoring is adequate so that appropriate alarms and indications are provided to dispatchers from all RAS sites and equipment. It is especially vital for the dispatcher to know if any parts of the RAS are not redundant since failure of that equipment would remove at least that part of the RAS from service. Failures within a non-redundant RAS may require the dispatcher to adjust the



system on an emergency basis so that neither arming of the RAS nor operation of the failed part of the RAS is necessary.

The RAS designer and operating personnel must have available adequate time stamping of RAS functions for the operation of the scheme and its components to document and diagnose operations as correct or incorrect. Scheme indication points may be categorized for this purpose as either “status” or “operating” with different time stamping requirements for each. Time resolution of 2-6 seconds (as might be provided through an EMS) for status points can be satisfactory (faster time resolution is also acceptable). Operating points will require sequence of events recorder(s) using time stamping to a resolution of one millisecond through GPS or similar clocks. As many points as feasible should be monitored so that the performance of the RAS can be evaluated. Minimum logging of scheme indication points should include:

### Status Points (time resolution 6 sec or less)

- Arming status,
- Status of operation or test switches,
- Equipment self-diagnostics and annunciation,
- Indication when a manually armed scheme should be armed or may be disarmed,
- Status of the equipment before and after the RAS action e.g., breaker status.

### Operating Points (time resolution 1 msec)

- Initiating device operation,
- Tone equipment transmitter operation,
- Tone equipment receiver operation,
- Tripping device operation.

The Supplemental Material for PRC-012-2 Attachment 1 includes the following minimum list of SCADA/EMS points:

- Whether the scheme is in service or out of service.
  - For RAS that are armed manually, the arming status may be the same as whether the RAS is in service or out of service.
  - For RAS that are armed automatically, these two states are independent because a RAS that has been placed in service may be armed or unarmed based on whether the automatic arming criteria have been met.
- The current operational state of the scheme (available or not).
- In cases where the RAS requires single component failure performance; e.g., redundancy, the minimal status indications should be provided separately for each RAS.
  - The minimum status is generally sufficient for operational purposes; however, where possible it is often useful to provide additional information regarding partial failures or the status of critical components to allow the RAS-entity to more efficiently troubleshoot a reported failure. Whether this capability exists will depend in part on the design and vintage of equipment used in the RAS. While all schemes should provide the minimum



level of monitoring, new schemes should be designed with the objective of providing monitoring at least similar to what is provided for microprocessor-based Protection Systems.

The RC for the RAS entity also requires status points from the Transmission Operator for each RAS, typically provided through an ICCP link, for the arming status: for each part of a redundant RAS, i.e., RAS A and RAS B. Each RC (RC West, SPP, BCH, or AESO) will identify specific monitoring points that are required for each RAS for which they have responsibility.

RAS designs are generally unique, and the RAS often operate on different principles than Protection Systems. Monitoring and organizing the status and alarm data appropriately can provide a helpful guide to operating personnel to control and diagnose scheme operations. For example, many owners with significant numbers of RAS design specific screens in their EMS to aid dispatchers in operating each RAS. Such screens may confirm scheme availability, summarize the arming status of the scheme and status of each action location, allow the dispatchers to arm or disarm the scheme, change locations to be armed for action, and list or summarize any alarms and their impact on the scheme.

### **5.0 Coordination with Protection, other RAS, and Control Systems**

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Often the purposes of RAS and equipment protection are different enough that little or no coordination, in the traditional sense used by protection engineers, may be necessary between the functions of each. However, RAS operation that depends on functions that are performed by protection relays will require a careful review. Protection / RAS interactions may include:

- System configuration changes due to RAS operation that might affect protective relay functions such as distance relay overcurrent supervision, breaker failure pickup, potential source switching, or other functions.
- If studies indicate that sustained low voltages in conjunction with elevated line flows may be expected during RAS operation, confirm that any protection settings on affected lines should not cause cascading outages related to the low system voltages. In general, if the potentially affected line relays are set to comply with PRC-023, even if the specific relays are not required to comply, this concern will often be satisfied.
- Designated out-of-step tripping devices should be provided on all components at planned system separation locations (out-of-step cut-planes). These devices should not operate on stable swings (see PRC-026-1) and should be coordinated to prevent tripping outside of the actual out-of-step cut-plane (perhaps applying power swing blocking).
- The Western Interconnection has historically experienced intensive synchronous swings and out-of-step conditions resulting in cascading outages at least partly due to undesired operation of distance relay protection. Out-of-step blocking features should be used for distance relays



away from identified out-of-step cut-planes if they may otherwise operate during system swings. The requirements and Supplemental Material of PRC-026-1 describe the technical aspects in detail, provide analysis methods to evaluate the risks, identify vulnerable locations, and briefly describe mitigations.

Another coordination example is a RAS that triggers action after an unsuccessful automatic reclose attempt on a transmission line. The RAS time delay after sensing the line outage but before initiating action must be longer than the breaker open interval, or the RAS action could be triggered by a positive status indication that the reclosing function has locked out. Successful single- or three-phase reclosing may allow temporary faults to clear and avoid the need for RAS actions. An unsuccessful reclose attempt may still require remedial action.

### 5.1 Multiple Applications in a Single Device

Many of today's microprocessor relays, programmable logic controllers, and other logic processors are highly flexible in allowing the user to program features necessary for specific applications. Various devices may be useful for both equipment protection and RAS operation. RAS functions could be easily programmed in available relays or logic controllers that are also used for equipment protection.

Mixing equipment protection and RAS functions in the same device raises separate coordination issues, especially related to operations and maintenance. Routine Protection System testing or changes could affect the availability and operation of the RAS. Observe the following precautions if protection and RAS functions are to be provided in the same device:

- Undesired operation of equipment protection relays has historically been an important cause of major disturbances characterized by intense swings, low voltages, and out-of-step conditions. The RAS is the next line of defense for the system. RAS security may be significantly improved when RAS devices are separate from equipment protection relays.
- There should be some association between the protection and RAS functions, e.g., line open status as a trigger for RAS action could be monitored by relays protecting that line terminal and the status could be communicated over the same relay-to-relay communication channel as is used for the line protection scheme.
- The device must be clearly labeled to identify the RAS functionality.
- Procedures or monitoring must notify the dispatcher before any modifications or testing in the device.
- Procedures or monitoring must notify the dispatcher before the device being removed from service.
- Procedures or monitoring must identify the impact that the outage or modification has on RAS operation.
- Procedures for testing protection logic and RAS logic after software upgrades.



- The effect of one scheme on the other, e.g., disabling one (protection) function may disable the other (RAS) function.

### 5.2 Other Remedial Action Schemes

Separate RAS may share certain loads or generation to be shed when RAS action is necessary. The scheme planners and designers need to closely examine such applications to be certain that such “shared” action will not result in shedding less load or generation (or other required action) than necessary for any credible contingencies.

### 5.3 Energy Management Systems

An EMS-based RAS is a form of mixing control and RAS functions in a single device. A utility’s EMS is more often used to provide dispatcher control commands, RAS arming calculations, and monitoring, but is also occasionally used for logic processing and scheme execution. Some RAS applications are not appropriate through the EMS, and even acceptable applications must be done with more care than for most other EMS applications.

A significant technical limit on EMS applicability to RAS is primarily related to data scan time between the EMS and remote RTUs (typically 2 to 4 seconds). The “round trip” of information from sensing status and levels, determining required action, and executing the action must be estimated to require at least 4 seconds (or twice the scan time). The following precautions must be kept in mind in applying EMS-based RAS:

- An EMS timing estimate of at least three to five times the scan time may provide an acceptable margin.
- The EMS cannot be fast enough to process logic and trigger RAS action to solve system transient stability related problems.
- Voltage control, thermal loading, or other problems that do not require action for at least 6-10 seconds or longer may be possible applications for an EMS-based RAS.
- An EMS-based RAS does not let the RAS owner avoid the scheme redundancy requirements described above.

Other technical and operating issues that must be addressed for an EMS-based RAS include:

- The EMS-based RAS must operate correctly even during wide-scale system disturbances that may tend to overburden the EMS with system operations and alarms.
- Consider the RAS impact if the EMS is unavailable.
- Even with an otherwise acceptable EMS-based RAS, a redundant non-EMS-based RAS may be required to ensure that the scheme operates properly even if the SCADA system data fails to update, as happened in the August 2003 Northeast blackout.
- The effects of loss of the DC source that powers the EMS must be considered.



- Validation methods for the incoming data must be considered, e.g., compare flow at both ends of a line and determine the appropriate response when a significant difference occurs, such as applying advanced state estimation methods. As a control example, if the EMS is used for automatic generation control, loss of telemetry data from an intertie or generation plant could ramp other generators up or down when such a change is not required.
- Some operations and maintenance issues may be more difficult to address with an EMS-based RAS than for a separate system design. For example:
  - Routine programming updates of the EMS data bases must be done with special attention to the effects on arming or triggering the RAS or disabling it.
  - Routine programming updates of the RTUs that include RAS functions must be done with special attention to the effects on RAS operation.
  - Routine field operations that usually have no immediate effect, such as lifting wiring or opening a test switch for a breaker status indication input to an RTU could trigger RAS action if that action is dependent on the breaker status indication to the RTU.
  - Functional testing procedures that securely simulate contingencies and induce system responses may be quite difficult to design.
- The operational precautions listed above for mixing RAS and protection functions in a single device must also be followed when implementing a RAS through an EMS.

## 6.0 Changing System Resource Mix

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The last few years have witnessed the beginning of a relatively rapid change in resources from traditional synchronous machines fueled by coal, oil, or natural gas to inverter-based resources (IBR) interconnected plants powered by solar (usually photo voltaic, PV) or wind turbines (several types, including inverters). These changes are accelerating as battery energy storage systems (BESS) are added to this mix. The ways that these resource changes may affect RAS have been identified in a recent WECC Remedial Action Scheme Reliability Subcommittee (RASRS) white paper and are summarized here.

1. Topology-based RAS typically rely on loss-of-line/element logic with less reliance on faster acting control systems. These systems use several methods to determine topology changes not driven by fault detection scenarios through planning studies. Most existing RAS are based on topology.
  - a. Topology-based RAS are not expected to be significantly affected by changes in the resource mix moving toward IBR. However, attention should be paid to how generation associated with topology-based RAS is armed to optimize post-contingency performance, i.e., consider arming IBR to trip ahead of traditional generation where sequential tripping is used.
    - i. RAS that depend on fault detection or identification may have issues as penetration of IBRs increases due to reduced fault duty available from IBRs compared to synchronous



- generators, including lack of negative sequence fault contributions. Higher source impedance ratios (SIR) may slow protection system operations, affecting fault-based RAS that mitigate transient stability issues.
- ii. Increased interconnection of BESS will change the way transmission planning groups study RAS since BESS will both discharge (generate) and charge (absorb) power to and from the grid unlike traditional generation and non-storage IBRs. If the BESS is not paired with another generation resource at the point of interconnection, charging the BESS from the transmission system may trigger a requirement for a RAS to be installed. Protection groups will also have to design the RAS hardware to adapt to the logic defined by planning groups, e.g., directional power elements to identify charging or discharging. Planning and protection groups will have to determine whether the BESS should be tripped immediately or ramped to keep it available during the event.
  - iii. IBRs with more sophisticated controls may provide primary frequency response, potentially affecting UFLS requirements and performance. IBRs may also provide primary voltage control, similar to traditional synchronous machines. These characteristics may be useful when designing RAS response to system events.

## 7.0 Operations and Test Procedures

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Planners, designers, and dispatchers must provide a description and operating procedures for the RAS to guide operations and maintenance personnel in the proper operation of the scheme. These descriptions and operating procedures will guide development of installation and test procedures, aid interpretation of alarm and status messages, and help identify scheme operations as correct or incorrect.

Due to the wide variety of RAS designs and implementations, and the potential for affecting BES reliability, it is important that periodic functional testing of a RAS be performed. A functional test provides an overall confirmation of the RAS to operate as designed and verifies the proper operation of the non-Protection System (control) components of a RAS that are not addressed in PRC-005. Protection System components that are part of a RAS are maintained in accordance with PRC-005.

The NERC Standard PRC-012-2 requires functional testing:

- At least once every six full calendar years for all RAS not designated as limited impact, or
- At least once every twelve full calendar years for all RAS designated as limited impact

A RAS is determined to be limited impact (or not) during the review process outlined in PRC-012-2 by the applicable RC.



Functional testing may be accomplished with end-to-end testing or a segmented approach. For segmented testing, each segment of a RAS must be tested. Overlapping segments can be tested individually negating the need for complex maintenance schedules and outages.

The interval between tests begins on the date of the most recent successful test for each individual segment or end-to-end test. A successful test of one segment only resets the test interval clock for that segment. A correct operation of a RAS qualifies as a functional test for those RAS segments which operate (documentation for compliance with Requirement R5 Part 5.1). If an event causes a partial operation of a RAS, the segments without an operation will require a separate functional test within the maximum interval with the starting date determined by the previous successful test of the segments that did not operate.

Usually, routine tests are easier to schedule when the RAS would not be armed due to system conditions (such as low intertie flows). These tests should be end-to-end in the sense that the scheme is manually armed, the initiating outage (or other event) is manually performed, and logic, communications, and actions at all sites are monitored for correct operation. It is not necessary to drop load or generation (if that is the RAS action) if an acceptable alternate test procedure is available (such as prior transfer of targeted load to another circuit) to prove the functionality of the “action” breakers.

Some utilities design their schemes specifically to make testing for scheme initiation, logic, and action fast, easy, safe, consistent, and nearly automatic from a single location through additional logic and test or operations switches. Automated testing tends to work better for smaller schemes because it is easier to define the worst-case scenarios that are most critical to scheme operation.

For large and complex schemes, it is especially important to identify critical scenarios in the test procedures and test the RAS as a system, though it can be impractical to test all features of the RAS over the full range of system operating conditions. The object in designing the test procedure will be to identify and test the conditions for arming, detection, activation, and completion that will cover the extreme system conditions for which the RAS is designed to protect the system.

## 8.0 RAS Review

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WECC has had a formal RAS review and approval process in place for many years to evaluate new and modified RAS. The RASRS provides this review. The primary function of the RASRS has been to promote the reliability of RAS within WECC by providing a multidisciplinary overview<sup>4</sup>:

- For new and significantly modified schemes.
- As requested by technical committees.
- For special technical problems regarding RAS outside the scope of other Subcommittees and Work Groups.

### 8.1 Scheme Review

The PRC-012-2 standard transferred the responsibility for RAS reliability reviews from WECC (and the RASRS) to the RC: AESO, BC Hydro, RC West, or SPP. WECC and the RASRS (renamed the Remedial Action Scheme Review Subcommittee, still RASRS) supports the RCs in their review processes. The format of the review process after transfer to the RCs is similar to the earlier WECC process. Smaller-scale, limited-impact schemes may be reviewed primarily by the individual RC, while larger schemes will also be reviewed by the RASRS.

All RAS that meet the NERC definition require review by the applicable RC. In addition to new schemes, functionally modified schemes and schemes proposed for retirement also require review.

- The PRC-012-2 Standard includes the following criteria identifying the functional modifications that require a RAS review:
  - Changes to System conditions or Contingencies monitored by the RAS.
  - Changes to the actions the RAS is designed to initiate.
  - Changes to RAS hardware beyond in-kind replacement; i.e., match the original functionality of existing components.
  - Changes to RAS logic beyond correcting existing errors.
  - Changes to redundancy levels; i.e., addition or removal.

The NERC Standard requires an evaluation by the applicable Planning Coordinator at least every five years for each scheme.

RC West has developed its own version of the RAS review documents. Any RAS-entity under the jurisdiction of RC West should use these documents (RC0690, RC0690A, RC0690B, RC0690C), which are available on the RC West [website](#), to document the necessary scheme information for review.

For RAS-entities not under RC West jurisdiction, the most recent version of the RASRS's review document<sup>6</sup> is available on the WECC website. The RAS designer should fill out a copy of this document and submit it and other related documentation through their RC, who will forward the material to the WECC RASRS website and notify the chair of the subcommittee in preparation for scheme review. Subcommittee review consists of a presentation by the owner's RAS design team and detailed technical discussion of the RAS's features, including any coordination with protection or other schemes, and any limitations. Scheme approval by the appropriate RC and WECC RASRS confirmation is (intended) to be obtained before the owner can depend on the RAS to solve the problems for which it was designed.

A preliminary design review by the RASRS may be feasible when time allows before the scheme has to be in service. The RASRS and some scheme designers have found such preliminary reviews helpful. The designer often can more efficiently accommodate the RASRS's concerns in the final scheme design, and the RASRS may be able to expedite the final review and approval.



With the approval of PRC-012-2 by FERC, the RAS approval and review are the responsibility of the applicable RC. As with all Standards, the RWG recommends that entities become familiar with and comply with the PRC-012-2 Standard.

### References

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1. North American Electric Reliability Council, NERC Planning Standard TPL-001-4, January 1, 2015
2. Western Electricity Coordinating Council - Relay Work Group, "Installing and Maintaining Protective Relay Systems", July 2015
3. Western Electricity Coordinating Council Remedial Action Scheme Reliability Subcommittee, "Western Interconnection RAS Review Guideline," Revised July 2019
4. North American Electric Reliability Council Standard PRC-006-2 — Automatic Underfrequency Load Shedding, November 13, 2014
5. North American Electric Reliability Council Standard PRC-010-1 – Assessment of the Design and Effectiveness of UVLS Program, November 21, 2013
6. Western Electricity Coordinating Council, "WECC Coordinated Off-Nominal Frequency Load Shedding and Restoration Plan," revised December 5, 2003
7. Western Electricity Coordinating Council, "Southern Island Load Tripping Plan," July 22, 1997
8. North American Electric Reliability Council Standard PRC-012-2 – Remedial Action Schemes, May 5, 2016
9. IEEE, Power System Relaying Committee, "Power System and Out-of-Step Considerations on Transmission Lines," Work Group D6, July 19, 2005
10. Western Electricity Coordinating Council Relay Work Group and Telecommunications Work Group, "Communications Systems Performance Guide for Electric Protection Systems," October 2022
11. Western Electricity Coordinating Council Telecommunications Work Group, "Guidelines for the Design of Critical Communications Circuits, November 18, 2010
12. Western Electricity Coordinating Council Critical Circuit Availability Calculation Appendix rev. 11-18-05
13. Western Electricity Coordinating Council, "WECC Guideline for Time Synchronization of Protection, Control and Monitoring"
14. Western Electricity Coordinating Council, "Application of Zone 3 Distance Relays on Transmission Lines," September 10, 1997
15. North American Electric Reliability Council, "Board Approved Blackout Recommendations - February 10, 2004"



16. North American Electric Reliability Corporation, “Special Protection Systems (SPS) and Remedial Action Schemes (RAS): Assessment of Definition, Regional Practices, and Application of Related Standards,” April 2013
17. North American Electric Reliability Corporation, “Protection System Reliability, Redundancy of Protection System Elements”, NERC System Protection and Control Subcommittee, Jan 2009.
18. IEEE, Power System Relaying Committee, “Redundancy Considerations for Protective Relaying Systems”, Working Group I19, March 6, 2007
19. Northeast Power Coordinating Council Reliability Reference [Directory #7](#), Special Protection Systems, Dec 2020.
20. North American Electric Reliability Corporation, “[Proposed Resource Loss Protection Criteria](#)”
21. North American Electric Reliability Corporation, “Frequency Response Annual Analysis, 2021”



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## Additional Resource Information

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### Version History

Modified Date	Modified By	Description
April 15, 1991	WSCC RWG	Original document development
November 28, 2006	WECC RWG	Extensive re-organization and modifications
January 2017	WECC RWG	Modification to recognize NERC RAS definition and PRC-012-2 standard
March 2021	WECC RWG	Modifications as the new PRC-012-2 becomes enforceable
July 2022	WECC RWG, TelWG, RASRS	Address RLPC, telecommunication language and minor review process description changes
September 7, 2022	EPAS	EPAS Approval, Recommend RRC Approval of Document