



Reliability and Resilience Webinar Kick-Off

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PNNL is operated by Battelle for the U.S. Department of Energy



Support and funding for this work provided by:
U.S. Department of State
Bureau of Energy Resources
Power Sector Program



Project background

- The U.S. Department of State, Bureau of Energy Resources, Power Sector Program (PSP), provides technical and regulatory support to the Central American regional electricity market.
- Under the PSP, Pacific Northwest National Laboratory delivers technical and analytic support to Ente Operador Regional (EOR, the Central American regional system operator).

EOR – U.S. DOS ENR – PNNL Collaboration



- Collaboration started in 2013
- 15 technical reports, 25+ presentations
- 7 PNNL tools adapted and trained Central American engineers
- 2,274 person-hours in trainings and technical discussions from PNNL studies



Reliability and Resilience Webinar Series Topics

Kick-Off and Remedial Action Schemes – April 14th and 21st, 2021

Resilience and Extreme Event Planning – May 12th and 19th, 2021

Transfer Capability and Coordinated Stability Studies – June 9th and 16th, 2021

Renewable Integration – July 14th, 2021

Final Session – August 18th, 2021



Reliability and Resilience Webinar Series Topic One: Remedial Action Scheme Design, Coordination and Modeling

Emily Barrett, Xiaoyuan Fan,
Juan Carlos Bedoya, Marcelo Elizondo



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Presentation Outline

Part 1 (April 14th, 2021)

- Introduction
- Standards and Practices in North America
- Overview of RAS Design Principles
- Coordination and Review Process Example from North America

Part 2 (April 21st, 2021)

- RAS Modeling Approaches for Operational Security Studies
- Deep Dive on RAS Modeling in PSS/E
- Ideas for Applications to Central America

Part 1

- Introduction
- Standards and Practices in North America
- Overview of RAS Design Principles
- Coordination Examples from North America

Better Controls are critical for a Fast-Evolving Grid

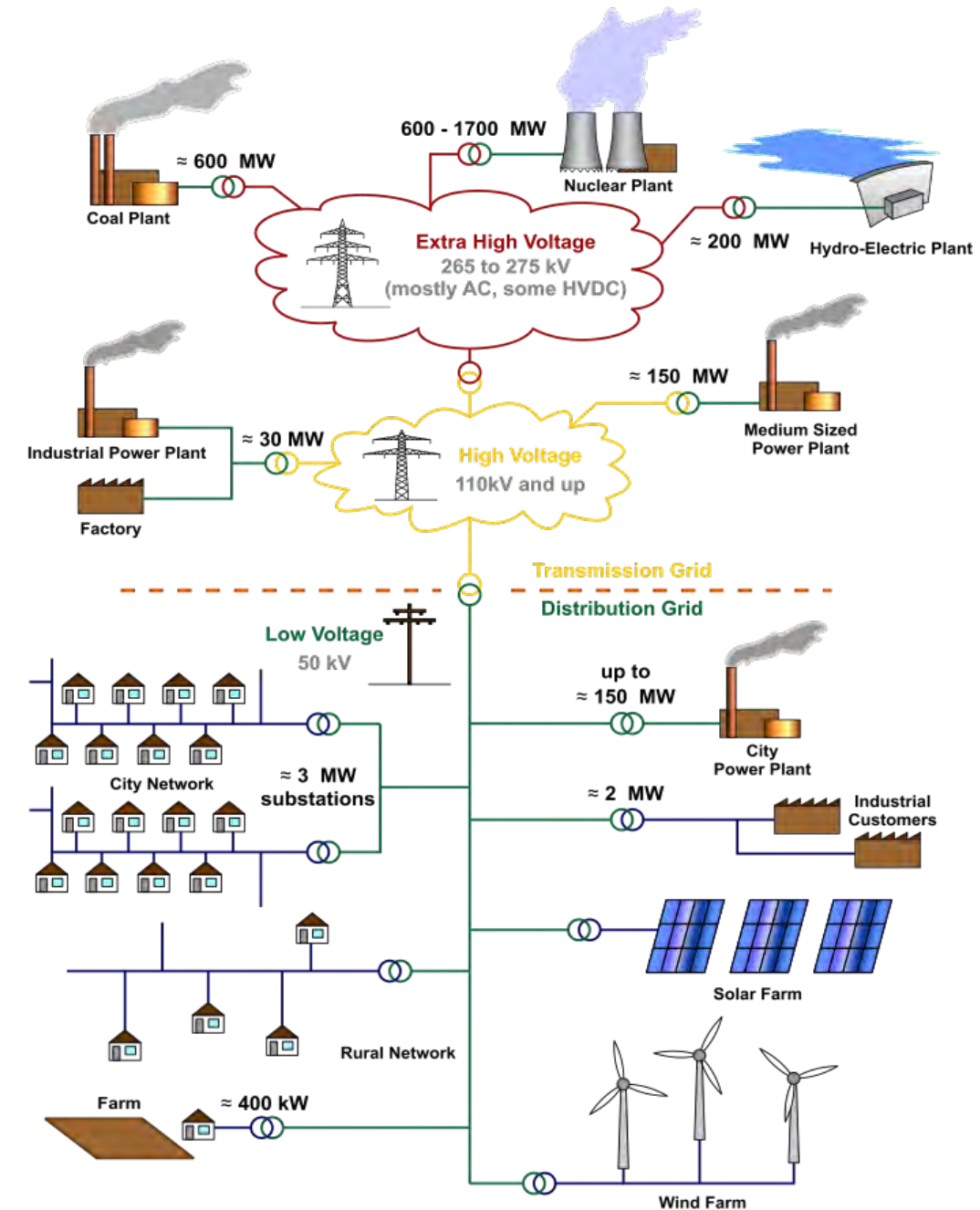
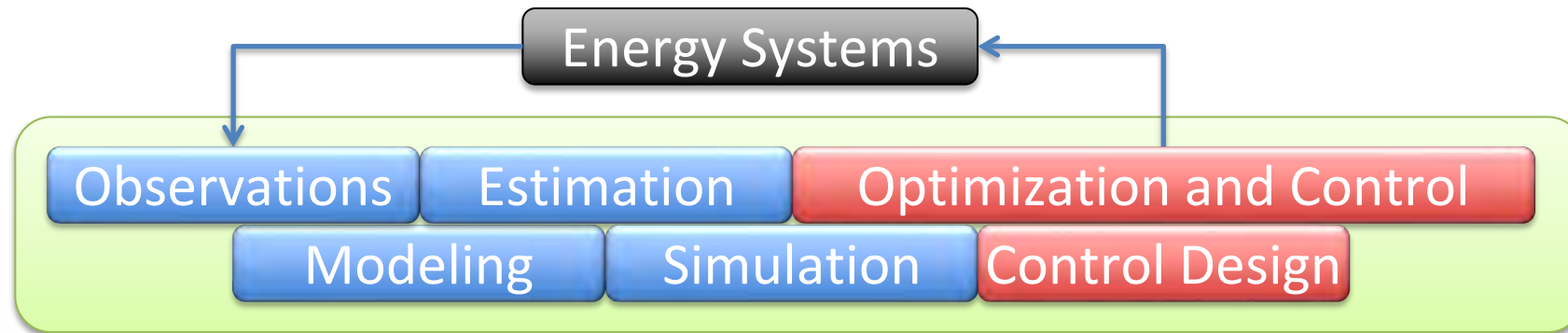
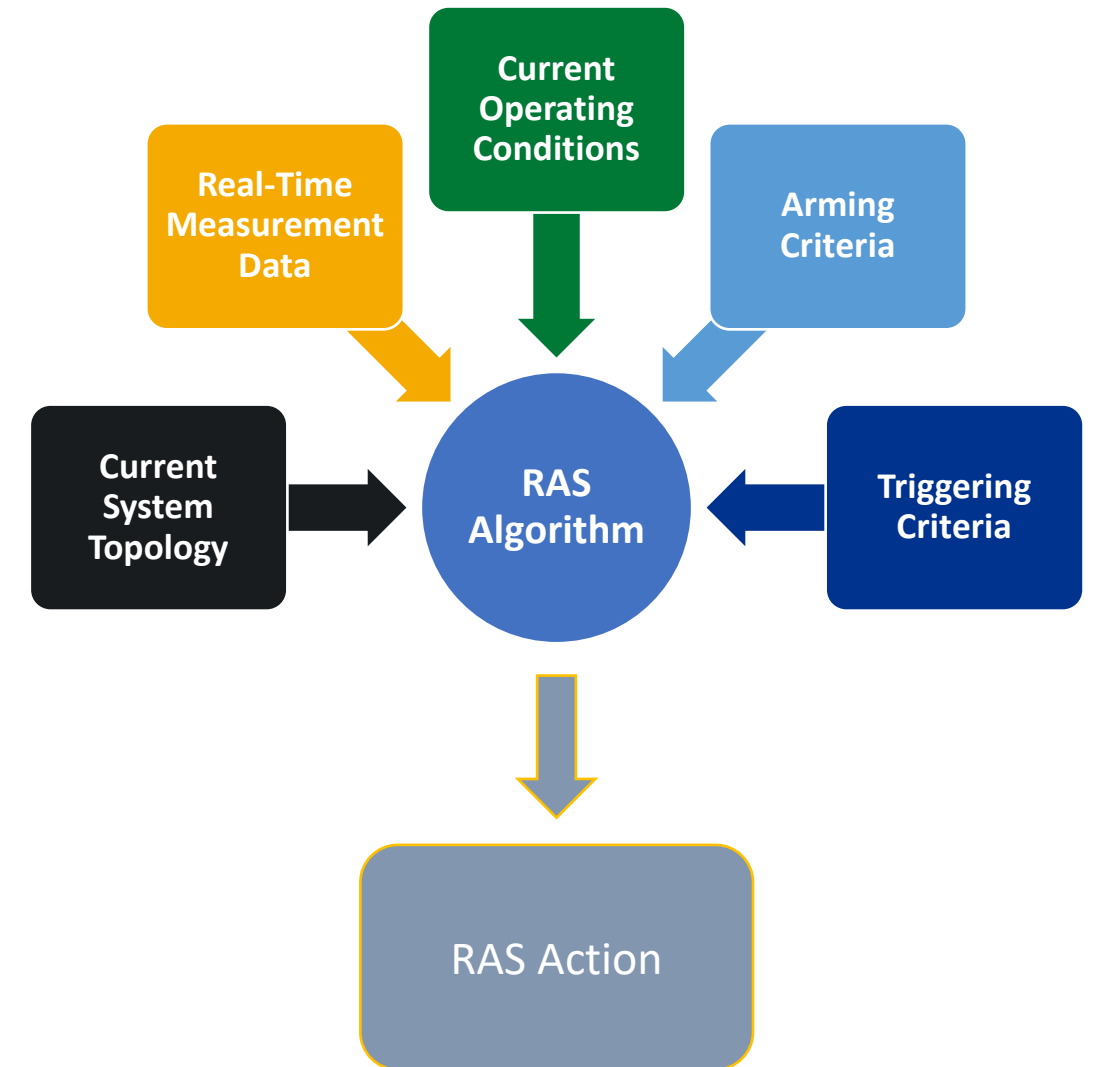


Figure 1. The word cloud for "Control" by Dr. Henry Huang, "Control Day at PNNL", Sep. 2018.

Figure 2. An illustration of electricity grid. Wikipedia, Own work Originally derived from [de:Datei:Stromversorgung.png](#), CC BY 3.0.

Automated Mitigation for Grid Contingency: Remedial Action Scheme

- ▶ Remedial action scheme (RAS) 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)[*].
 - One of the most important alternative control options in operation, to handle post-fault stability issues.



[*]The North American Electric Reliability Corporation (NERC) Glossary of Terms

Value of RAS in Grid Planning and Operation

- ▶ Remedial action scheme (RAS) can
 - Enable renewable generation integration while deferring transmission expansion
 - Increase system operating limits and asset utilization
 - Enable advanced grid control applications

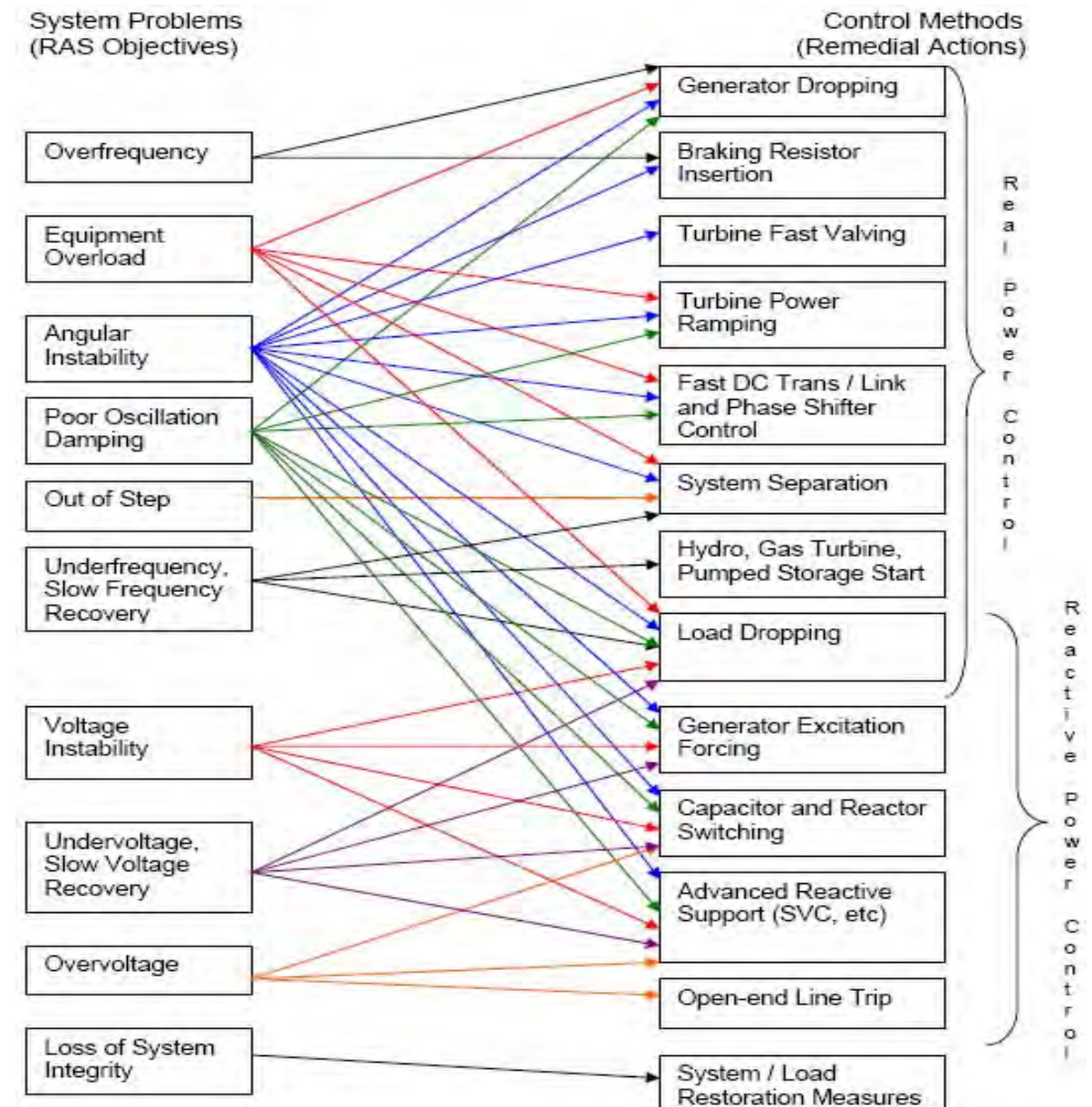


Figure 3. Common RAS objectives and control methods [*].

[*] Jun Wen, P. Arons and W. E. Liu, "The role of Remedial Action Schemes in renewable generation integrations," *2010 Innovative Smart Grid Technologies (ISGT)*, Gaithersburg, MD, USA, 2010, pp. 1-6, doi: 10.1109/ISGT.2010.5434770.

Example from North America

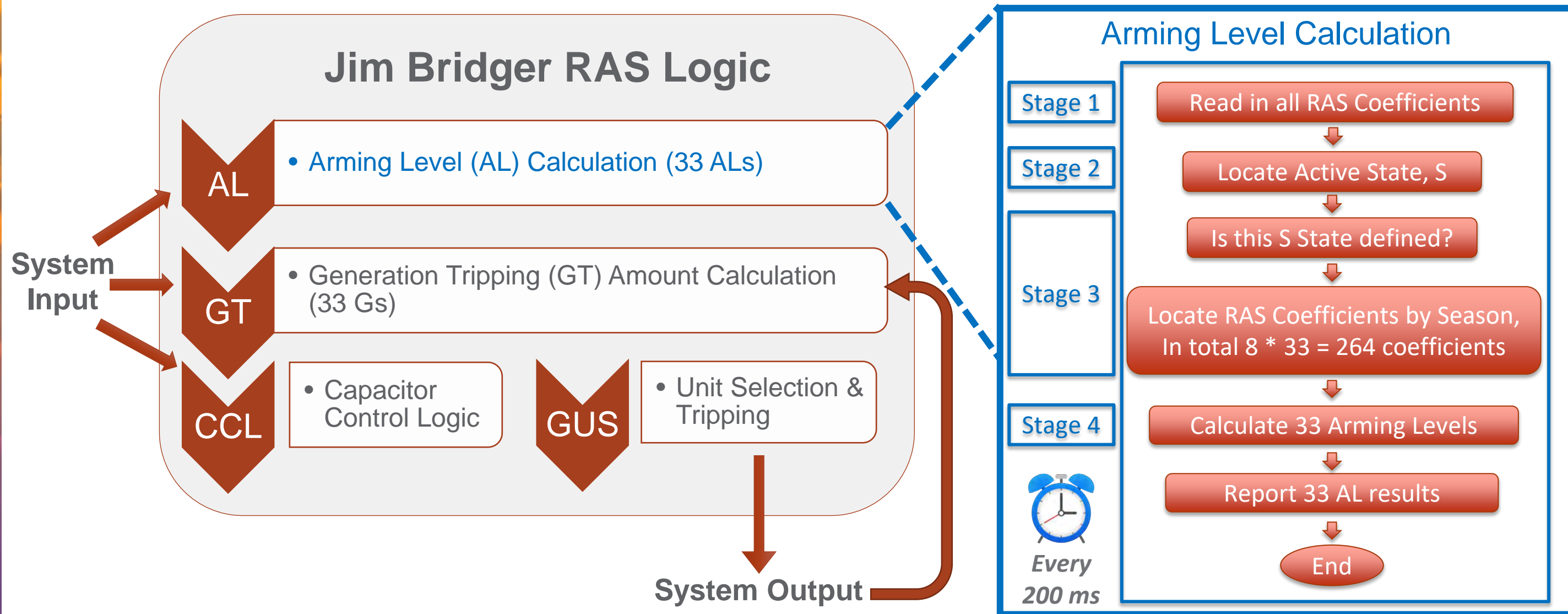


Figure 4. The operation logics and arming-level calculation for U.S. Western Interconnection Jim Bridger RAS [*].

[*] Fan X., et al. 2019. *Adaptive RAS/SPS System Setting for Improving Grid Reliability and Asset Utilization through Predictive Simulation and Controls: A Use Case for Transformative Remedial Action Scheme Tool (TRAST): Jim Bridger RAS Evaluation and Analysis*. PNNL-29522. Richland, WA.

Why RAS modeling matters in Planning & Operation?

- Integrating RAS Modeling into system planning and real-time operation can significantly improve the simulation accuracy and prevent false alarm and miss detection.

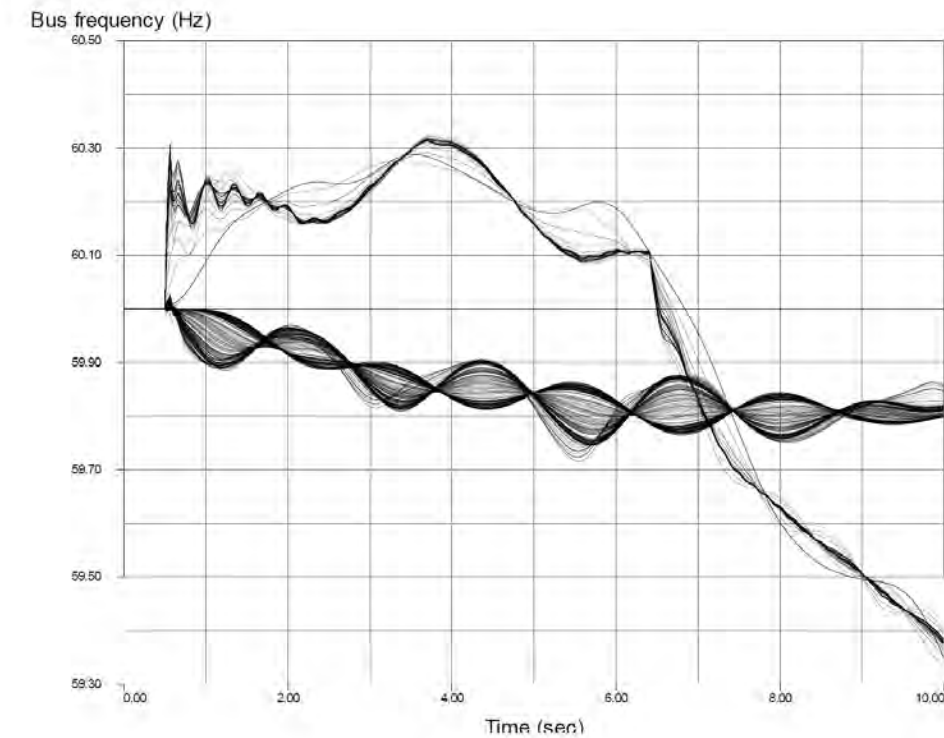
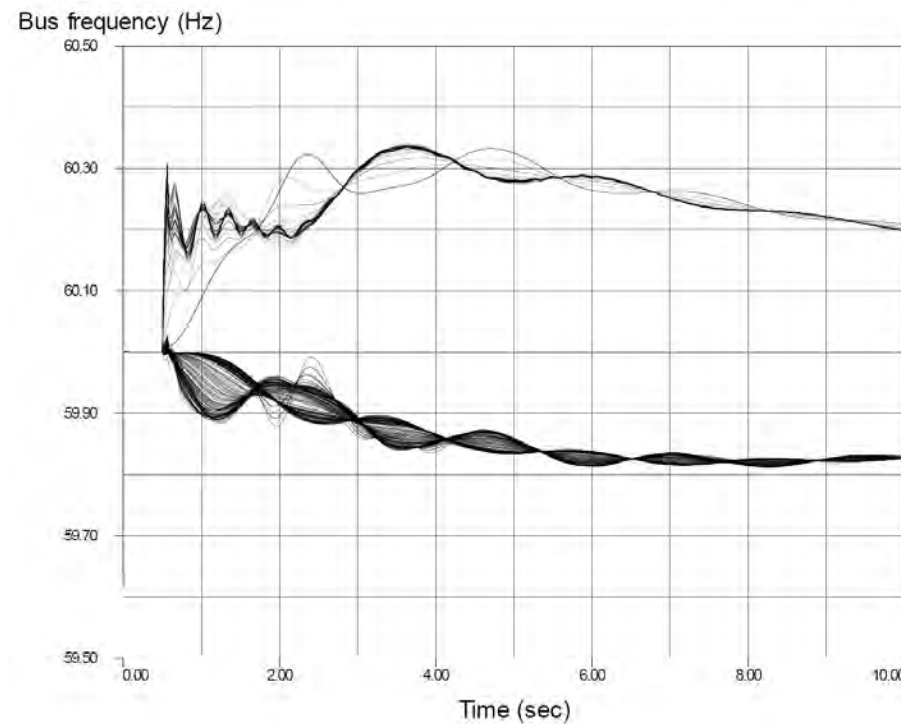


Figure 6. Peak Reliability TSAT Simulation for real grid event, 2017 US-Canada Separation. (a) Simulated frequency with OOS modeled, (b) Simulated frequency with OOS removed [*].

Importance of Regional Coordination for RAS

2011 Southwest Blackout

“Even though protection systems operated as designed, they made matters worse, which calls into question whether they were properly designed, studied, or coordinated.”

- Heather Polzin, FERC post-event forensics team lead

- September 8, 2011 – 3:38 pm PDT
- Lasted for 12 hours
- More than 2.7M customers left without electricity in parts of Arizona, Southern California and Baja California
- \$12-18 M of food waste
- Several sewage pumping stations failed, resulting in water safety concerns

Examples from Central America

- ▶ Action of transferred trip ECS (EDALTBV): trips Mexico-SER interconnection when: (1) transfer grows above 300 MW; and (2) voltage at THP, Mexico drops to 97% or less
 - Strong contribution from Mexico after a large generation trip in SER could cause the transfer to grow above 300MW in a matter of seconds
 - EOR reported 14 actions of this ECS, September 2016 to November 2017 [*]
 - EOR reported 21 actions of this ECS, January 2019 to December 2020
- ▶ Action of oscillations ECS: trips Mexico-SER interconnection when undamped interarea oscillations are detected
 - Undamped interarea oscillations are likely to be triggered by the sudden loss of generation
 - EOR reported 51 actions of this ECS, January to November 2017 [**]
 - EOR reported 32 actions of this ECS, January 2019 to December 2020
 - From October to December 2020, new adjustments were implemented in some generation units of the SER to mitigate the oscillations, since then no new oscillations have been registered
- ▶ Mexico's import trip is likely to follow a large single generation contingency in SER – impactful to system

[*] EOR, "Eventos en el SER donde ha operado el esquema EDALTBV, (SER Events that EDALTBV scheme [transferred trip ECS] has operated)," Nov. 2017

[**] EOR, "Eventos en el SER donde ha operado el esquema ESIM004_OSC, (SER Events that ESIM004_OSC scheme [oscillations ECS] has operated)," Nov. 2017

Examples where EDALTIBV operated

- July 8, 2019 event: initiated by generation trip in Panama (145 MW)
- March 2019 event: initiated by 230kV line trip in Panama (356 MW)

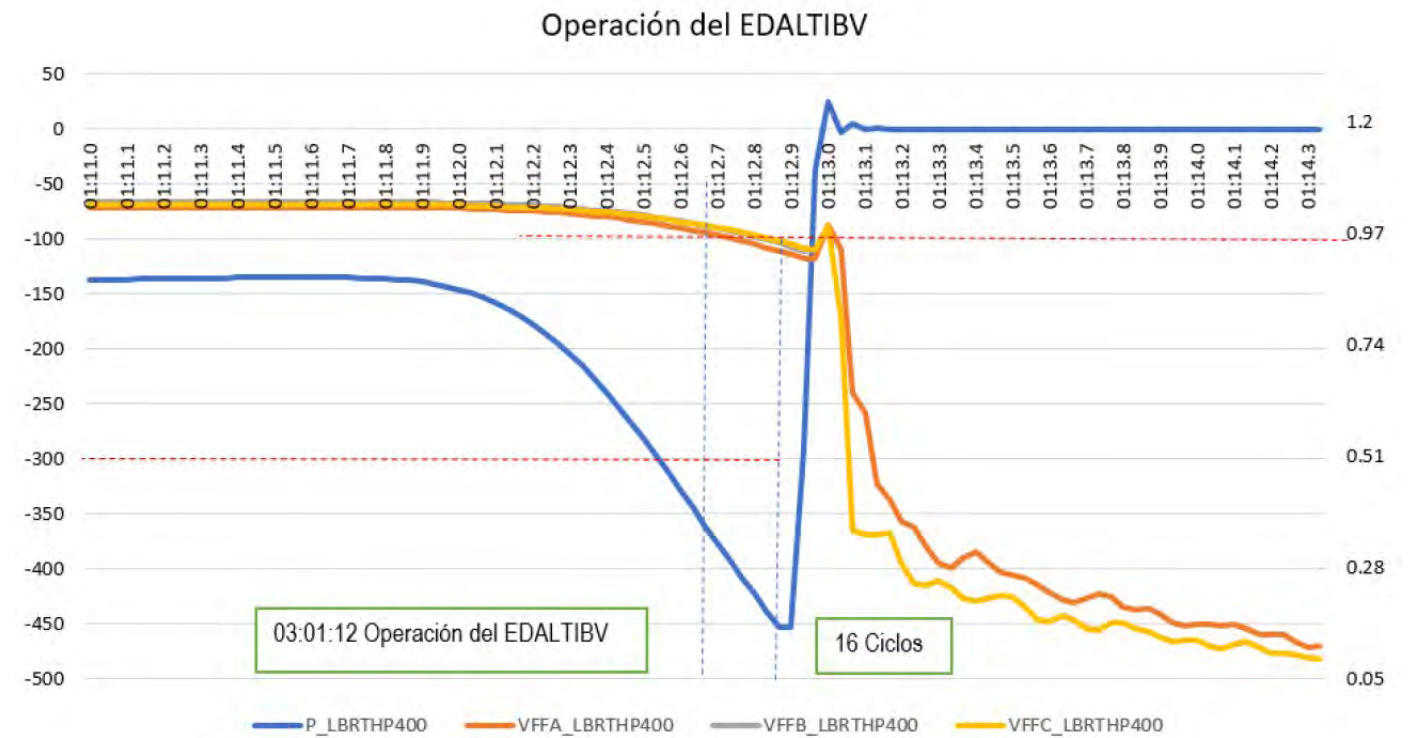


Figure source: "Informe evento 11 marzo 2019 a las 03:01 horas," EOR, March 2019

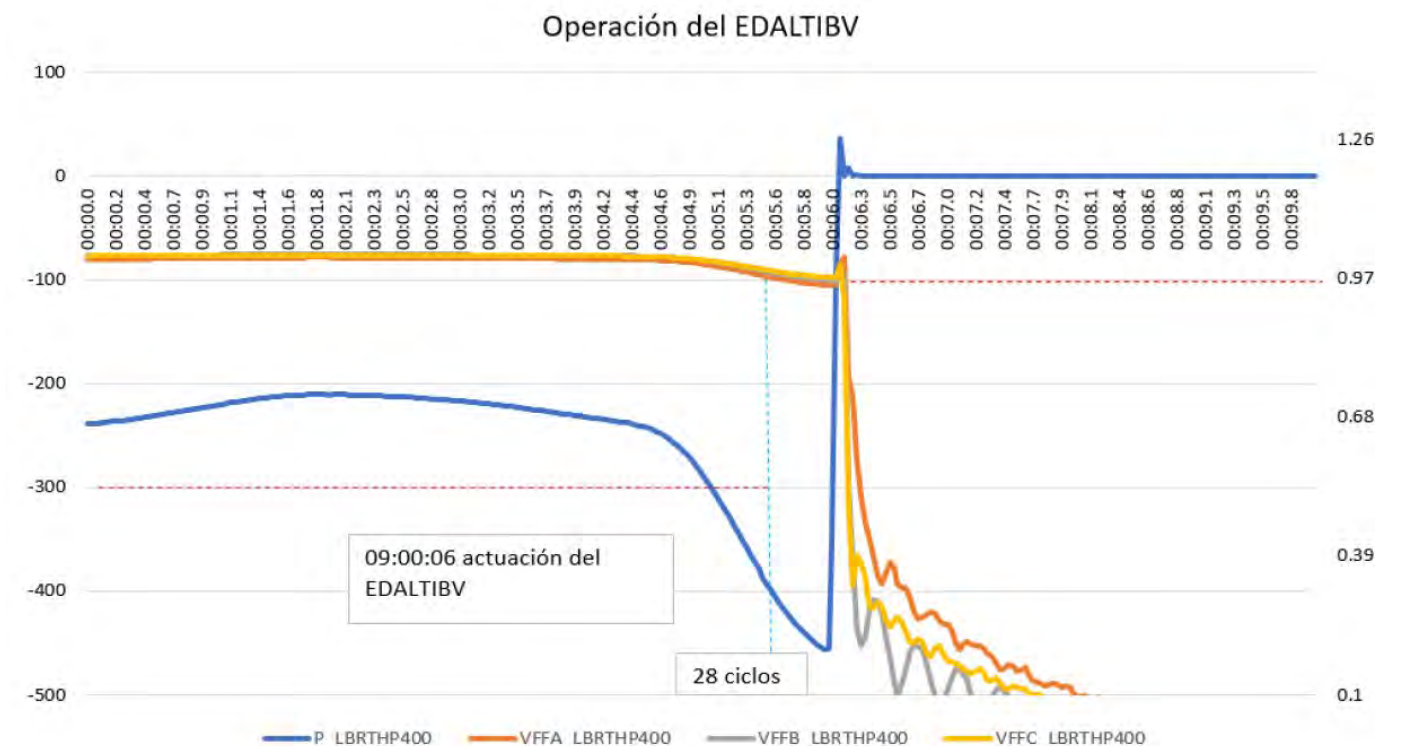
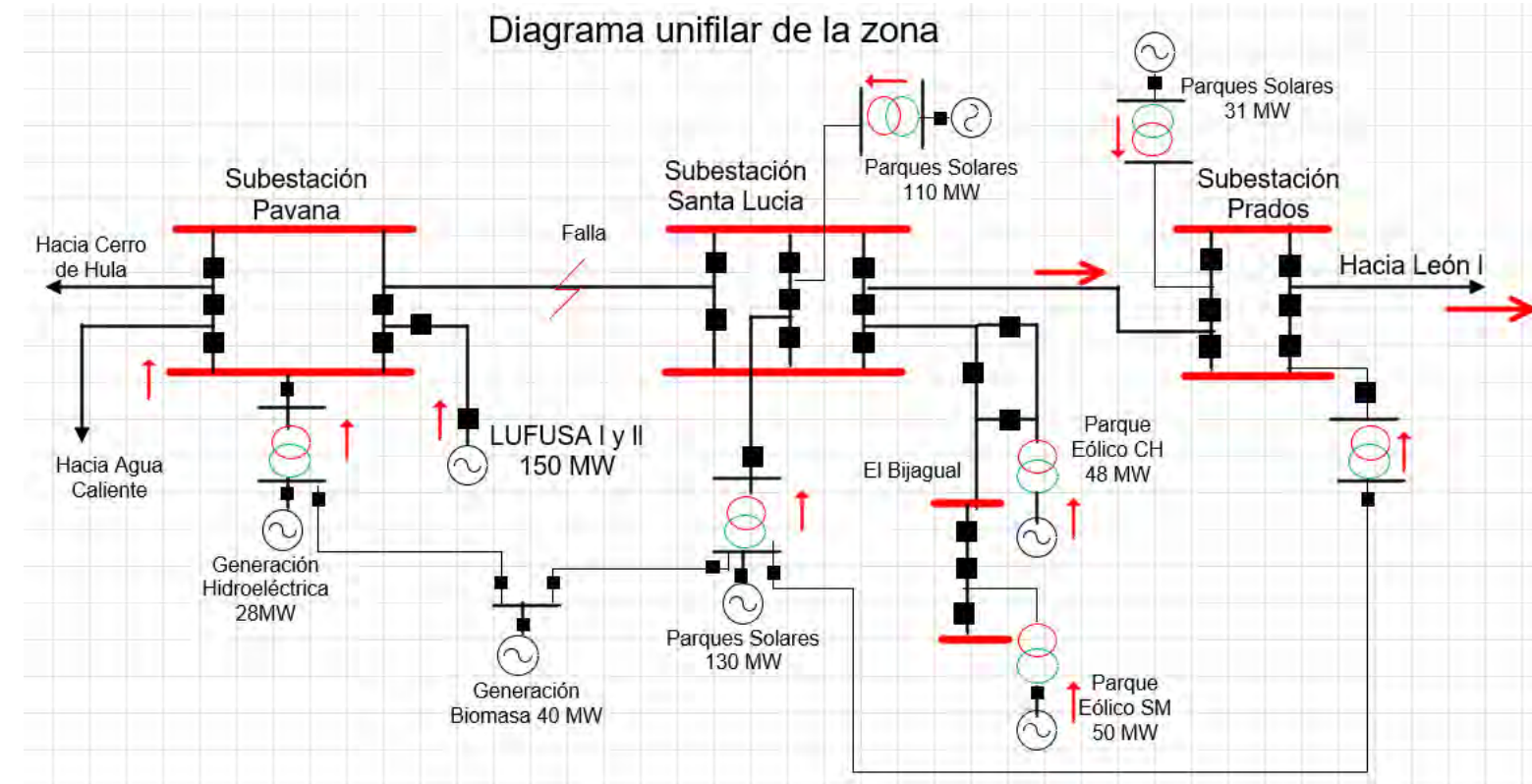


Figure source: "Informe evento 08 julio 2019 a las 09:00 horas," EOR, July 2019

Honduras ECS

- New ECS L615
 - If two conditions met:
 - ✓ line Pavana – Santa Lucia trips, and
 - ✓ power flow in line Santa Lucia – Prados ≥ 100 MW
 - ECS action:
 - ✓ All photovoltaic generation (9 plants) limited to 30% of installed capacity – maximum reduction of 170 MW



Standards and Practices in North America



NERC Standards

Remedial Action Scheme (RAS)

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.

WECC:
Western
Electricity
Coordinating
Council

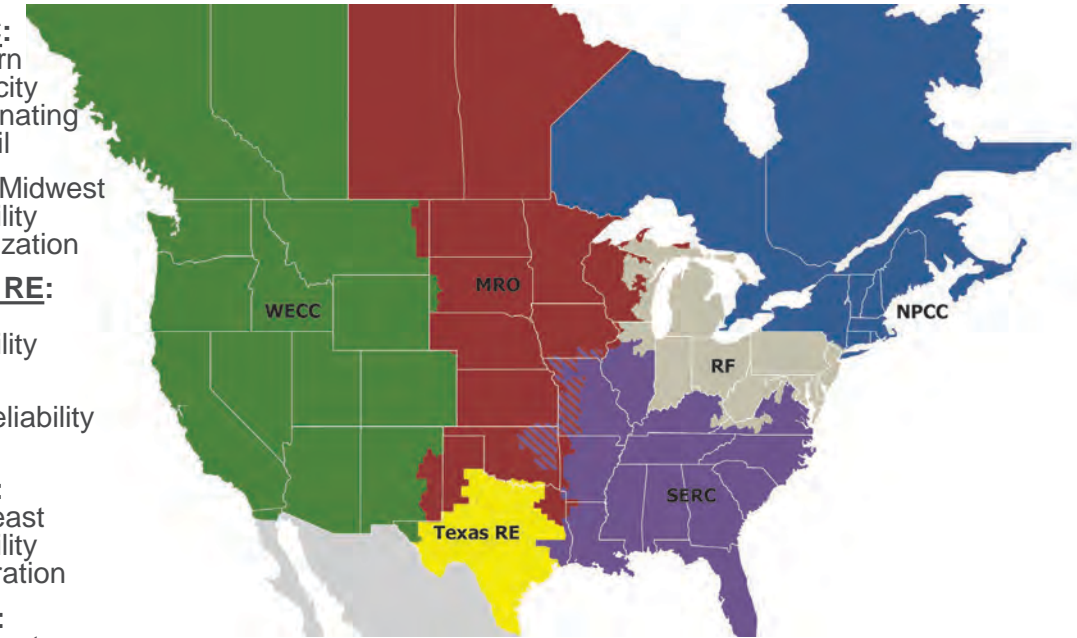
MRO: Midwest
Reliability
Organization

Texas RE:
Texas
Reliability
Entity

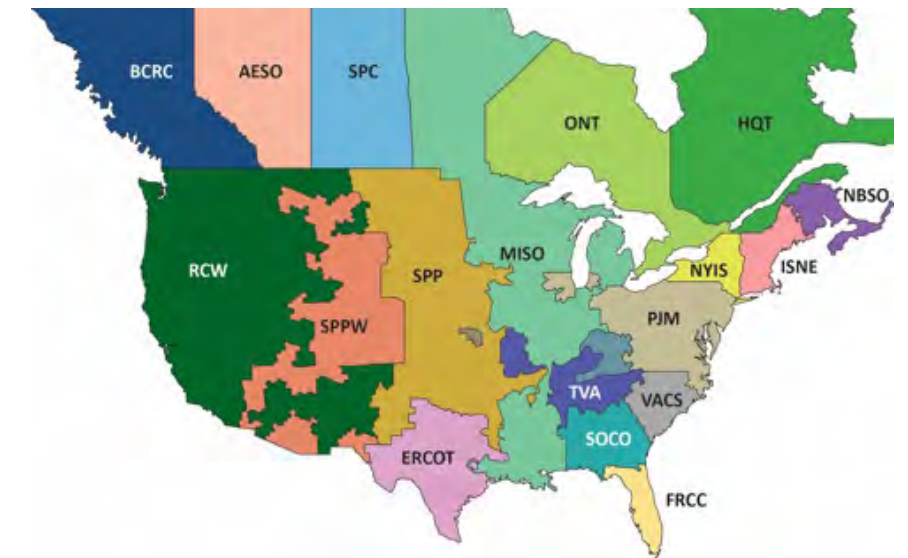
RF: Reliability
First

SERC:
Southeast
Reliability
Corporation

NPCC:
Northeast
Power
Coordinating
Council



NERC Electric Reliability Organization (ERO) enterprise encompasses Six Regional Entities Organizations
(<https://www.nerc.com/AboutNERC/keyplayers/Pages/default.aspx>)



NERC Reliability Coordinators as of December 3, 2019
(<https://www.nerc.com/pa/rrm/TLR/Pages/Reliability-Coordinators.aspx>)

NERC Standard PRC-012-2 - Overview

PRC-012-2: Remedial Action Scheme (RAS)

Purpose:

- To ensure that Remedial Action Schemes (RAS) do not introduce unintentional or unacceptable reliability risks to the Bulk Electric System (BES).

Applicable to:

- Functional Entities:
 - Reliability Coordinator
 - Planning Coordinator
 - RAS-entity – the Transmission Owner, Generator Owner, or Distribution Provider that owns all or part of a RAS



PRC-012-2 Also incorporates qualitative description of requirements violation risk factors and time horizon impact.



NERC Standard - PRC-012-2 - Requirements

■ Summary of Requirements:

- New or modified RAS must be reviewed and approved by the Reliability Coordinator prior to implementation.
- Planning Coordinators must evaluate RAS every 5 years.
- All RAS operations or failures to operate must be analyzed.
- If deficiencies in RAS are identified, Corrective Action Plans must be developed.
- RAS should be field tested once every 6 years, or 12 years if designated as limited impact.
- Reliability Coordinator must maintain and update a RAS database annually.



■ Compliance enforcement:

Subject to enforcement from Jan 1st, 2021, however, previous standards currently incorporate many of these requirements.

NERC Standard - PRC-012-2

Remedial Action Scheme (RAS)

PRC-012-2

“...since the last audit, unless directed by its Compliance Enforcement Authority to retain specific evidence for a longer period of time as part of an investigation.”

- PRC-012-2 is new, but previous standards are incorporated here.
- Entities have not yet been audited for compliance to this Standard.



Retirement and Withdrawal of Various PRC Standards

- PRC-012-1 – Remedial Action Scheme Review Procedure – Withdrawn
- PRC-013-1 – Remedial Action Scheme Database – Withdrawn
- PRC-014-1 – Remedial Action Scheme Assessment Requested Retirements – Withdrawn
- PRC-015-1 – Remedial Action Scheme Data and Documentation – Retired
- PRC-016-1 – Remedial Action Scheme Misoperations – Retired

NERC PRC-012-2

New RAS (or new functionality), Modifications, or Retiring standards

R1: Responsible: RAS-entity.

What to do?: Provide supporting documentation (maps, one-line diagrams, location, identification, corrective action plans), to the Reliability Coordinators (RC), according to Attach. 1.

VRF and TH: [Medium] [Operation planning].



R2: Responsible: Reliability Coordinator (RC), after receiving documentation from R1.

What to do?: Address R1 request within **four months**. Perform a review of RAS. Provide feedback (Attach. 2) – Reports, checklist, communication records.

VRF and TH: [Medium] [Operation planning].

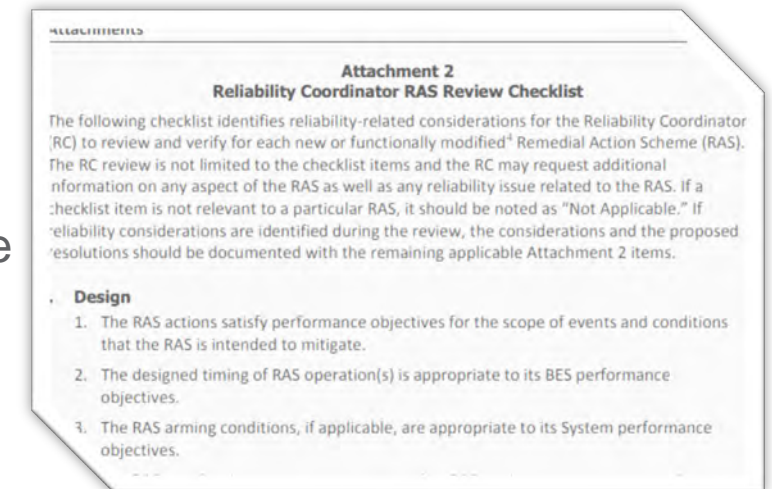


R3: Responsible: RAS-entity, after receiving RC feedback.

What to do?: Solve each issue to obtain approval of the RAS from each reviewing Reliability Coordinator.

VRF and TH: [Medium] [Operation planning].

VRF and TH: Violation Risk Factor and Time Horizon Impact.



NERC PRC-012-2

Planning Coordination - Evaluation Requirements

R4: Responsible: Planning Coordinator

How often?: At least every **5 years**.

What to do?:

Perform RAS evaluations that:

- RAS mitigates the system condition(s) or contingency(ies) for which it was designed.
- RAS avoids adverse interactions with other RAS, and protection and control systems.
- For limited impact RAS (LIRAS), the inadvertent operation or failure does not cause BES cascading, uncontrolled separation, angular instability, voltage instability, voltage collapse, or unacceptably damped oscillations.
- For all RAS except LIRAS, the possible inadvertent operation or malfunction satisfies:
 - BES shall remain stable.
 - Cascading shall not occur.
 - Applicable Facility Ratings shall not be exceeded.
 - BES voltages within post-contingency limits (defined by Transmission Planner and the Planning Coordinator).
 - Transient voltage responses within acceptable limits (defined by Transmission Planner and the Planning Coordinator).

Provide evaluation results, including identified deficiencies, to each reviewing:

- Reliability Coordinator
- RAS-entity
- Impacted Transmission Planner and Planning Coordinator

NERC PRC-012-2

RAS entity – After RAS operation or failure

R5: Responsible: RAS entity

When?: Within **120 days** after RAS operation or failure, or on a mutually agreed upon schedule.

What to do?:

- Participate in analyzing the RAS operational performance to determine whether:
 - The System events and/or conditions appropriately triggered the RAS.
 - The RAS responded as designed.
 - The RAS was effective in mitigating BES performance issues it was designed to address.
 - The RAS operation resulted in any unintended or adverse BES response.
- Provide the results of RAS operational performance analysis that identified any deficiencies to its reviewing Reliability Coordinator(s).

VRF and TH: [Medium] [Operation planning].

R6: Responsible: RAS entity

When?: Within **6 months** of:

- Being notified of a deficiency in its RAS pursuant to Requirement R4, or
- Notifying the Reliability Coordinator of a deficiency pursuant to Requirement R5
- Identifying a deficiency in its RAS pursuant to Requirement R8

What to do?:

- Participate in developing a Corrective Action Plan (CAP) and submit the CAP to its reviewing Reliability Coordinator(s).

VRF and TH: [Medium] [Operation planning, Long term planning].



NERC PRC-012-2

RAS entity – Corrective Action Plan (CAP) Implementation and Testing

R7: Responsible: RAS entity

What to do?:

- Implement the CAP.
- Update the CAP if actions or timetables change.
- Notify the Reliability Coordinator(s) if CAP actions/timetables changes when the CAP is completed.

VRF and TH: [Medium] [Operation planning-Long term planning].

R8: Responsible: RAS entity

What to do?:

- Participate in performing a **functional test** of each of its RAS to verify the overall RAS performance and the proper operation of non-Protection System components

When?:

- Once **every 6 years** for all RAS **not** designated as limited impact.
- Once **every 12 years** for all RAS designated as limited impact.

VRF and TH: [High] [Long term planning].

NERC PRC-012-2

Reliability Coordinator – Database updating

R9: Responsible: Reliability coordinator

What to do?: Update a RAS database containing, at a minimum, the information in Attachment 3:

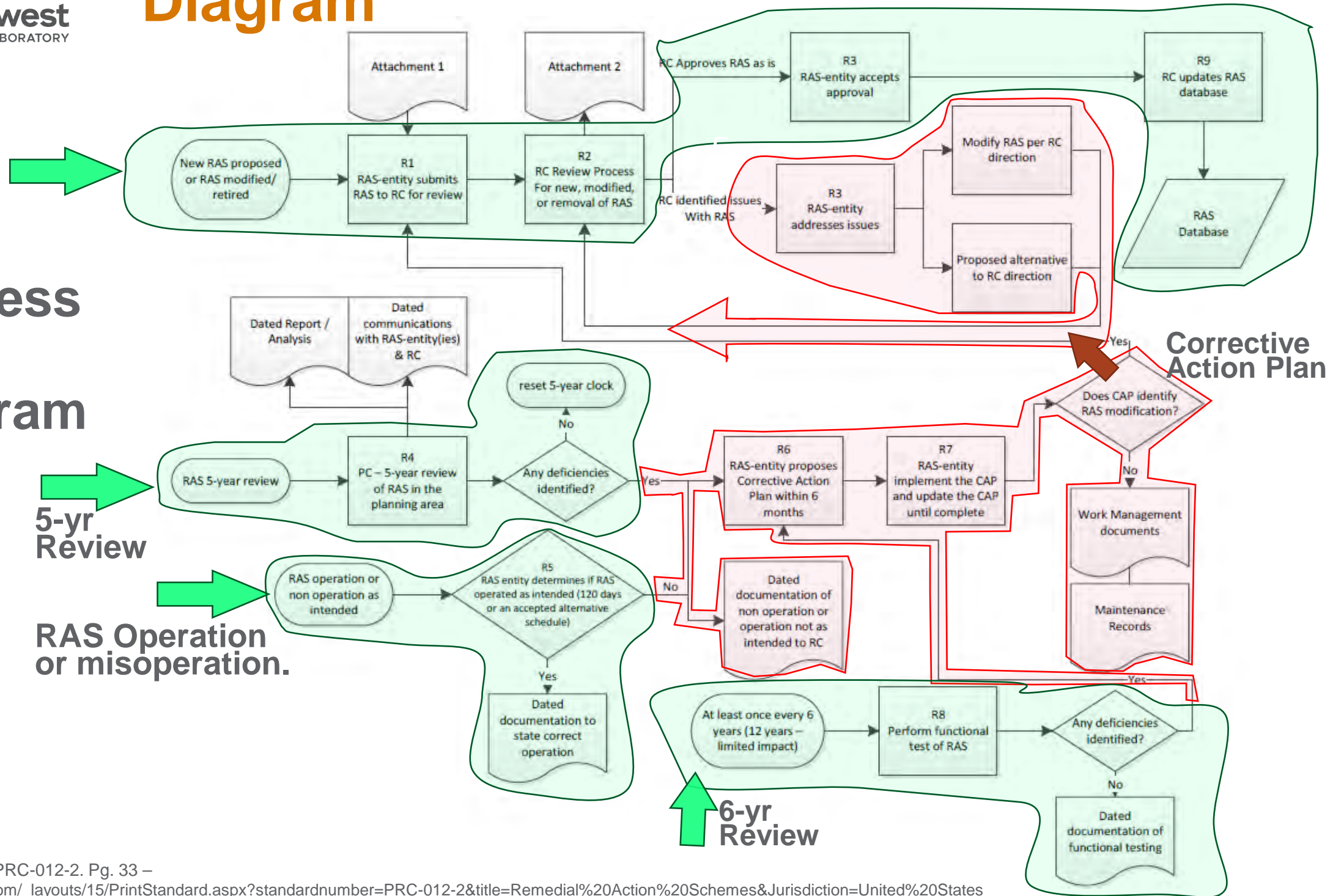
- RAS name.
- Each RAS-entity and contact information.
- Expected or actual in-service date; most recent RC-approval date (Requirement R3); most recent evaluation date (Requirement R4); and date of retirement, if applicable.
- System performance issue or reason for installing the RAS (e.g., thermal overload, angular instability, poor oscillation damping, voltage instability, under- or over-voltage, or slow voltage recovery).
- Description of the Contingencies or System conditions for which the RAS was designed (i.e., initiating conditions).
- Action(s) to be taken by the RAS.
- Identification of limited impact RAS.
- Any additional explanation relevant to high-level understanding of the RAS.

When?: Once **every 12 months**.

VRF and TH: [Lower] [Operation planning].

NERC Standard - PRC-012-2 – Process Flow Diagram

Process Flow Diagram



NERC Standards: PRC-017-1 RAS Maintenance and Testing

PRC-017-1 - Remedial Action Scheme Maintenance and Testing

▪ Purpose:

- To ensure that all Remedial Action Schemes (RAS) are properly designed, meet performance requirements, and are coordinated with other protection systems. To ensure that maintenance and testing programs are developed and misoperations are analyzed and corrected

▪ Applies to:

- Transmission Owner that owns a RAS
- Generator Owner that owns a RAS
- Distribution Provider that owns a RAS

NERC Standards: PRC-017-1 RAS Maintenance and Testing

PRC-017-1 - Remedial Action Scheme Maintenance and Testing

▪ Requirements:

R1. Maintenance and testing program(s) in place, including:

- RAS identification (including relays, instrument transformers, communications systems, batteries).
- Documentation of maintenance and testing intervals and their basis.
- Summary of testing procedure.
- Schedule for system testing.
- Schedule for system maintenance.
- Date last tested/maintained.

R2. RAS entity shall **provide documentation** of the program and its implementation to the appropriate Regional Reliability Organizations and NERC on request within **30 calendar days**.

NERC Standards Considerations

Why is the Remedial Action Scheme (RAS) review assigned to the Reliability Coordinator?

- Reliability Coordinators (RCs) have the widest-area reliability perspective.
- Some NERC regions have as many as 30 PCs for one RC, while other regions have a single PC and RC for the same area.

Why is the five-year evaluation of Requirement R4 assigned to the Planning Coordinator?

- The evaluation includes RAS mitigation of the System condition, RAS avoidance of adverse interactions with other RAS, protection and control systems, the impact of inadvertent operation, and the impact of a single component failure.
- The evaluation of these items involves modeling and studying the interconnected transmission system, similar to the planning analyses performed by Planning Coordinators.

Why are RAS classifications not recognized in the standard?

- There are two categories in PRC-012-2: “limited impact” and “all other RAS”.
- RAS classification by function was suggested to differentiate the reliability risks between planning and extreme RAS for continuity with PRC-012-1 R1.3; however, the standard drafting team concluded the classification is unnecessary.
- The distinction between planning and extreme RAS is captured in Requirement R4, Part 4.1.5 and Attachment 1, item III.4 of PRC-012-2 that relates to single component failure; consequently, there is no need to have a formal classification for this purpose.

WECC Standards (WECC-CRT-2, before NERC PRC-012-2)

Remedial Action Scheme Review and Assessment Plan

WECC-CRT-2 - PRC-(012 through 014)- (Sept 17, 2013 – Effective date Jan 1, 2014)

Purpose

- Establish a documented RAS review procedure to ensure compliance per PRC-012-0.
- Establish a RAS database.
- Meet the Regional Reliability Organization / Reliability Assurer requirements.

Applicability

- Transmission Owner, Generator Owner, Distribution Provider, or Reliability Assurer (WECC).

Requirements

- WECC shall create and maintain a WECC RAS info database.
- Reporting parties shall provide data according to WECC formats (Attach. 1).
- WECC designates the **RAS reliability subcommittee (RASRS)** to review procedure for proposed and existing RASs within the Western Interconnection to meet the NERC reliability standards (TPL).
- The reliability assurer (WECC) designates the **operation committee (OC)** as responsible to approve the WECC review procedure for proposed and existing RASs.
- Reporting parties shall review the WECC RAS database for accuracy and report any changes to the Reliability Assurer (WECC), **no later than Dec 31 (each year)**.
- RAS owner shall assess its RAS(s) for operation effectiveness, at least once each **five years**.
- Reporting parties shall retain documentation to support Attachment 2 data for the most recent assessment study and provide it to WECC **within 30 days** upon request.

Remedial Action Scheme Information Sheet Explanations Attachment 1

Major WECC RAS	Party. (That initial classification is subject to review by the RASRS.) If this scheme is in WECC Reliability Standard PRC-STD-003, Table 3, Major WECC RAS List, enter the number from the list. If the scheme is not on the Major WECC RAS List, enter NA.
Operating Procedure	If the Transmission Owner(s), Generator Owner(s) and Distribution Provider(s) that owns all or part of an existing or proposed RAS as reported by the Reporting Party has a written operating procedure for this scheme, provide the identifying procedure number or title. If no operating procedure is available, enter NONE or NA.
Design Objectives	Data required to describe Design Objectives — contingencies and system conditions for which the scheme was designed.
Operation	Data required describing Operation — The actions taken by the scheme in response to Disturbance conditions.

Attachment 2

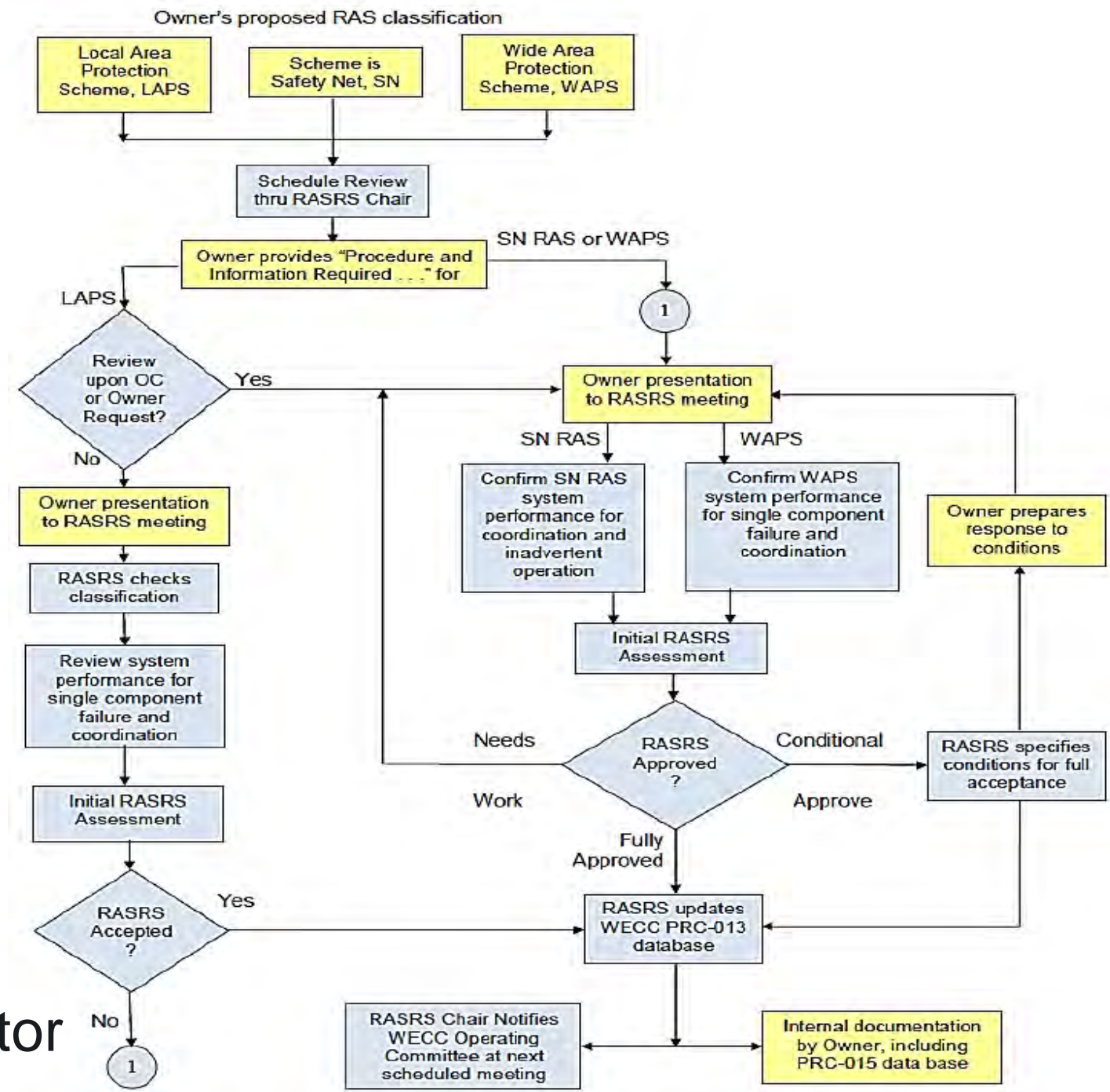
RAS Name	
Reporting Party	
(The Reporting Party for this entry will always be the same as the Reporting Party entry listed in the Reporting Party field of Attachment A.)	
Group Conducting this RAS Assessment	
Assessment Date	
Review the scheme purpose and impact to ensure proper classification, is it (still) necessary, does it serve the intended purposes, and does it continue to meet current performance requirements.	
This RAS assessment included the following:	
Study Years	
System Conditions	
Contingencies analyzed (select what applies)	
N-1	
N-1-1	
N-2	
Extreme	
Date when the technical studies were completed	
Does this RAS comply with NERC standards and WECC Criteria?	
Discuss any coordination problems found between	

Overview of RAS Design Principles



Initiation of New RAS

- ▶ Transmission Planning Engineer
 - New Power Plant
 - New Transmission Line project
 - New Substation project
 - New technology (PMUs)
- ▶ Transmission Operation Engineer
 - Emerging credible contingency
 - Transmission congestion
 - Transient stability
 - Undamped oscillation
- ▶ Interconnection Reliability Coordinator
 - Review/Approve RAS function design
 - Collect RAS model



Revision & Upgrade of Existing RAS

- ▶ Transmission Planning Engineer
 - Additional Power Plant
 - Additional Transmission Line project
 - Additional Substation project
 - New technology (PMUs)
- ▶ Transmission Operation Engineer
 - Emerging credible contingency
 - Transmission congestion
- ▶ Protection Engineer
 - Asset Management
- ▶ Interconnection Reliability Coordinator
 - System Reliability Issues
 - Review/Approve RAS revision & Upgrade
 - Update RAS model database

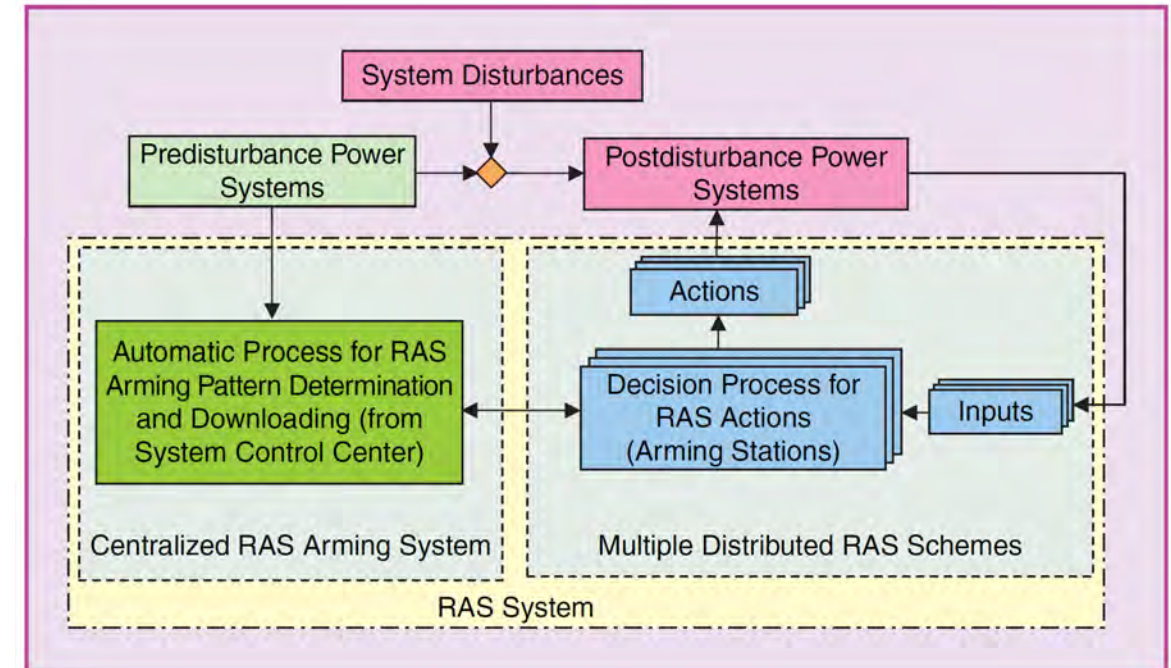


Figure (above). A functional diagram of Canadian utility BC Hydro's automatic RAS system. [*]

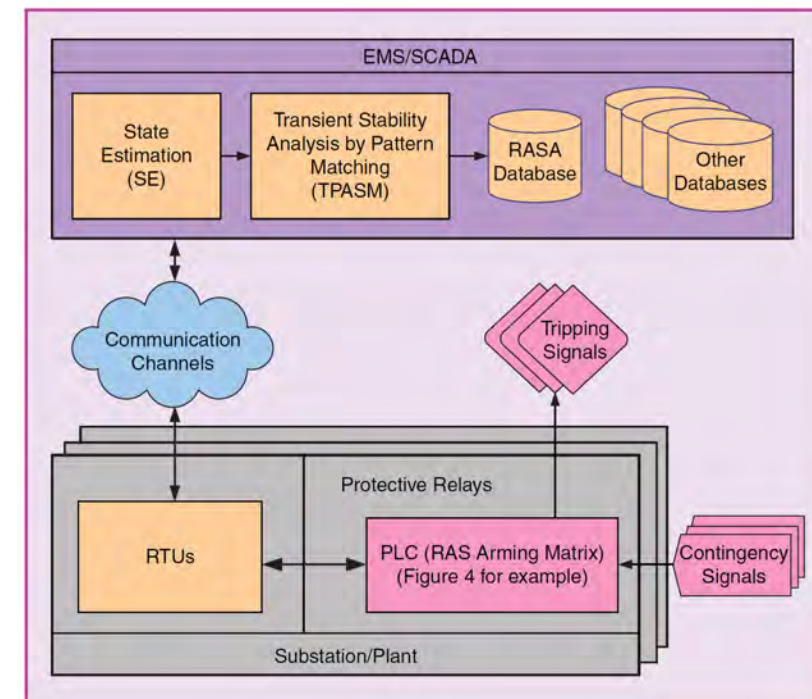


Figure (left). The integrated EMS/ RAS system at Canadian utility BC Hydro. [*]

[*] Ziwen Yao; Veera Raju Vinnakota; Qing Zhu; Charles Nichols; Greg Dwernychuk; Tito Inga-Rojas, Forewarned Is Forearmed: An Automated System for Remedial Action Schemes, IEEE Power and Energy Magazine, 2014, Vol. 12, No. 3, pp. 77-86.

Decommissioning of inactive RAS

- When a RAS is no longer needed, it should be decommissioned timely and properly
- RAS decommissioning criteria [*]
 - Information necessary to ensure that the RC is able to understand the physical and electrical location of the RAS and related facilities
 - A summary of applicable technical studies and technical justifications upon which the decision to retire the RAS is based
 - Anticipated date of RAS retirement
- Potential impact if not properly decommissioned
 - 2011 U.S. Southwest Blackout, SDG&E S-Line RAS

[*] RC West and California ISO, “PRC-012 Remedial Action Schemes – RAS Review Checklist.”, Reliability Coordinator Procedure, No. RC0689A, Version 1.0, effective date 1/1/2021. <http://www.caiso.com/Documents/RC0690A.pdf>

Communication Infrastructure Planning for RAS

- Communication redundancy through completely separated communication systems
- Common methods
 - Mirrored Bits/ Digital Microwave
 - RFL-9745/Microwave
 - Mirrored Bits/ Digital Leased Line
 - Local communications
 - Fiber
 - Power Line Communication (PLC)
 - Others
- VHF/UHF Repeaters should also be noted in the system

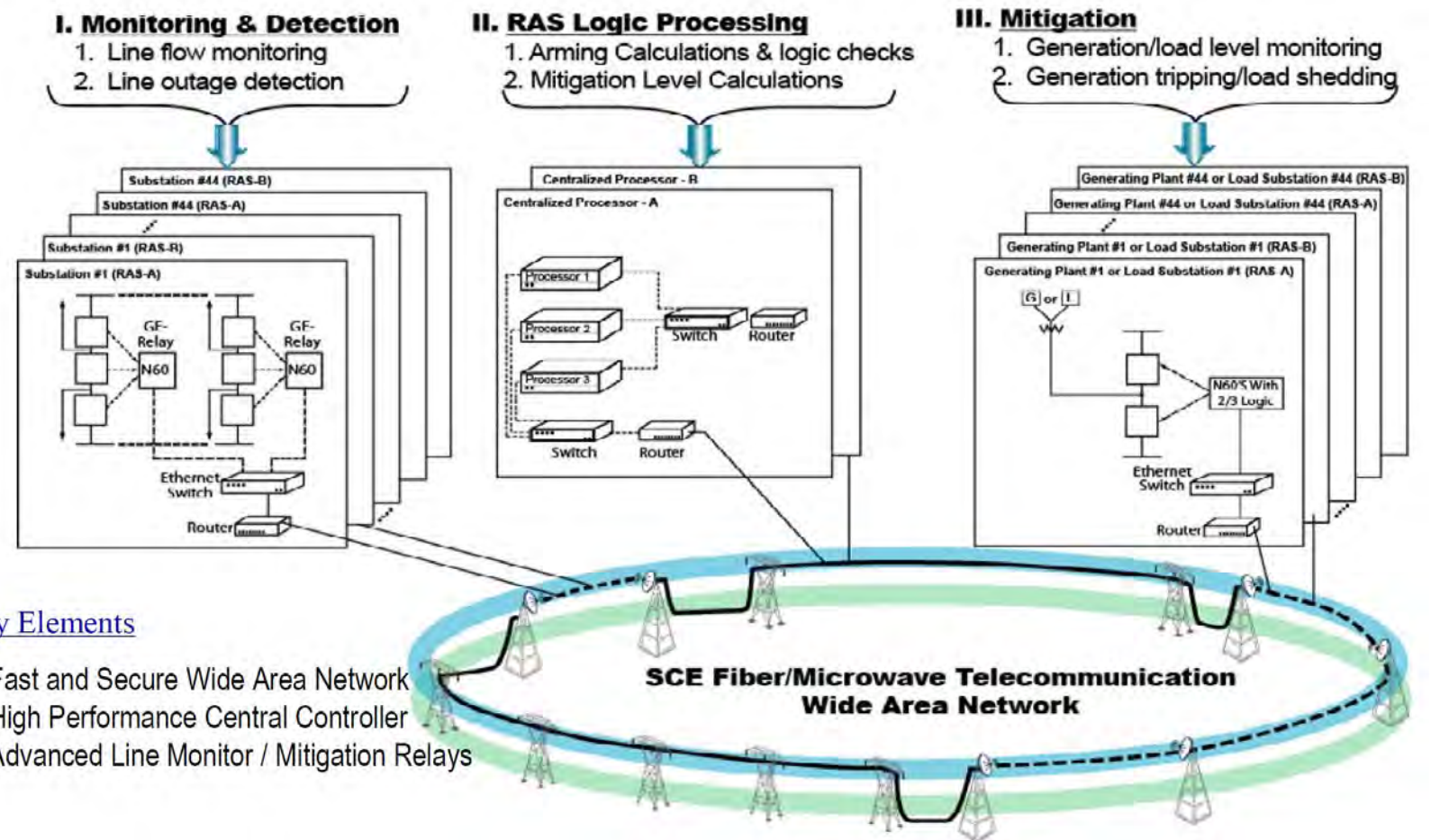


Figure. The Communication infrastructure for Southern California Edison's C-RAS. [*]

[*] A. Johnson, J. Wen, J. Wang, E. Liu and Y. Hu, "Integrated system architecture and technology roadmap toward WAMPAC," *ISGT 2011*, Anaheim, CA, USA, 2011, pp. 1-5, doi: 10.1109/ISGT.2011.5759148.

Coordination and Review Process Example from North America



Western Interconnection RAS Review

What is the WECC RAS Review?

- RAS review establishes a **framework** for submitting RAS information to the WECC RASRS or the affected RC.
- All elements of a RAS are subject to RAS NERC requirements.
- Minimum requirements for system performance are laid out in the transmission planning (TPL) standards and related WECC criteria.

What is NOT a RAS:

- Protection Systems installed for detecting faults on BES elements and isolating the faulted elements.
- Schemes, ***comprised of only distributed relays***, for automatic under-frequency load shedding (UFLS) and automatic under-voltage load shedding (UVLS).
- Automatic reclosing schemes.
- Controllers that switch series/shunt reactive devices, FACTS, phase-shifting/variable-frequency/tap-changing transformers; if located at and monitor quantities solely at the same station as the element being switched.
- Schemes that automatically de-energize a line for a non-fault operation when one end of the line is open.
- Generator controls: AGC, AVR, power system stabilizers, fast valving, and speed governing.

1. Welcome, Call to Order, Introductions

Gene Henneberg, Remedial Action Scheme Reliability Subcommittee (RASRS) Chair, called the meeting to order at 3:02 p.m. on February 26, 2020. A quorum was present to conduct business. A list of attendees is attached as Exhibit A. Mr. Henneberg asked attendees to introduce themselves.

2. Review WECC Antitrust Policy

Evan Paull, Reliability Specialist, read aloud the WECC Antitrust Policy statement. The meeting agenda included a link to the posted policy.

3. Approve Agenda

Mr. Henneberg introduced the proposed meeting agenda.

By consensus, the RASRS approved the agenda.

4. SCE RAS Removal

Yan Zou and Andrew Lopez, Southern California Edison Company (SCE), gave a presentation on the Inland Empire RAS.

On a motion by David Beach, the RASRS approved the removal of the Inland Empire RAS.

The presentation is posted to the [WECC website](#).

5. Public Comment

No comments were received.

6. Upcoming Meetings

March 17–18, 2020 Salt Lake City, UT

July 28–29, 2020 Salt Lake City, UT

November 10–11, 2020 Salt Lake City, UT

<https://www.wecc.org/Administrative/2020-02-26%20RASRS%20Minutes.pdf>

Western Interconnection RAS Review

When is RAS Review Required?

- Before placing a new RAS in service.
- Before being functionally modified, i.e.,:
 - System conditions or contingencies monitored by the RAS,
 - The actions the RAS is designed to initiate,
 - RAS hardware beyond in-kind replacement (i.e., match the original functionality of existing components),
 - RAS logic beyond correcting existing errors,
 - Redundancy levels.
- In the event of operational deficiencies, i.e.,:
 - Intended RAS operations that do not meet expected system performance levels,
 - Accidental RAS operations that result in system performance outside performance standards,
 - RAS failures to operate that result in system performance outside performance standards.
- Retirement of a RAS.

Note: Schemes proposed for retirement should first be evaluated by the same planning group that reviewed the studies that resulted in the RAS installation/modification (WECC Studies Subcommittee-StS or appropriate Planning Coordinator

- 1. Welcome, Call to Order, Introductions**

Gene Henneberg, Remedial Action Scheme Reliability Subcommittee (RASRS) Chair, called the meeting to order at 8:03 a.m. on July 28, 2020. A quorum was present to conduct business. A list of attendees is attached as Exhibit A. Mr. Henneberg asked attendees to introduce themselves.
- 2. Review WECC Antitrust Policy**

Evan Paull, Engineer, read aloud the WECC Antitrust Policy statement. The meeting agenda included a link to the posted policy.
- 3. Approve Agenda**

Mr. Henneberg introduced the proposed meeting agenda.
On a motion by Milt Patzkowski, the RASRS approved the agenda.
- 4. Review and Approve Previous Meeting Minutes**

Rachel Smith, Administrative Assistant, introduced the minutes from the meeting on March 3, 2020. Milt Patzkowski, PacifiCorp (PAC), made corrections to the presenters.
On a motion by Milt Patzkowski, the RASRS approved the minutes from March 3, 2020.
- 5. Review of Previous Action Items**

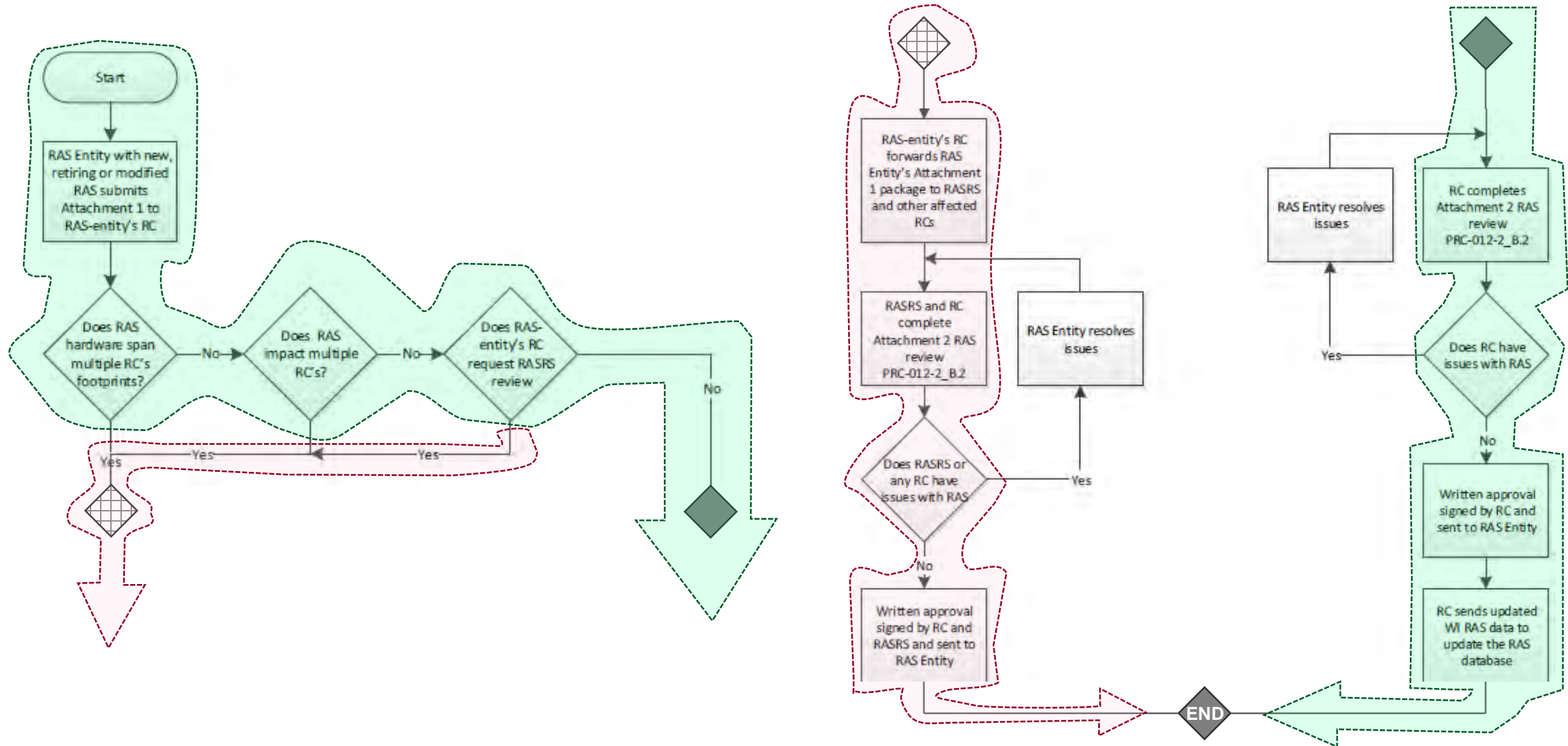
Mr. Paull reviewed action items carried over from the RASRS meeting on March 3, 2020. Action items that are not closed and will be carried forward can be found [here](#).
- 6. General Business**

The RASRS discussed the current membership. Any future updates will be sent to Ms. Smith.

<https://www.wecc.org/Administrative/2020-07-28%20RASRS%20Minutes.pdf>

Western Interconnection RAS Review

WECC RAS Review Process



Western Interconnection RAS Review

System Performance Criteria Outside an RC Area

Event type	Transient Volt dip limits	Min. Transient Frequency Limits	Post Transient voltage deviation limits
Single contingency	$\leq 20\%$ for >20 cycles at load buses or, $\leq 25\%$ at load buses or, $\leq 30\%$ at non-load buses.	≥ 59.6 Hz for 6 cycles at load buses	Not to exceed 5% at any bus
Double or multiple contingency	$\leq 30\%$ at any bus or, 20% for >40 cycles at load buses.	≥ 59.0 Hz for 6 cycles at load buses	Not to exceed 10% at any bus

Notes: For example, a single contingency disturbance *in one system* will not cause a transient voltage dip greater than 20% *in another system* for more than 20 cycles (load buses) or exceed 25% (load buses) or 30% (non-load buses) at any time other than during the fault.

RAS is reviewed by the affected RC, but will also need a larger review from RASRS for schemes that include:

- RAS hardware that spans the footprints of multiple RCs
- An affected RC requests review by the RASRS.
- Failure of RAS to operate when appropriate or an incorrect RAS operation may result in any of the following:
 - Violations of the Table - System Performance Criteria Outside an RC Area,
 - Maximum firm load loss ≥ 300 MW,
 - Maximum generation loss ≥ 1000 MW.

This is congruent with similar criteria as WECC had previously used to define Local-Area Protection Schemes (LAPS), Wide-Area Protection Schemes (WAPS), and Safety Nets (SN).

Western Interconnection RAS Review

Attachment 1: Supporting Documentation for RAS Review

RAS-entity must document and provide to the reviewing RC.

General Information:

- Maps, one-line drawings, substation and schematic drawings (physical and electrical location) of the RAS and related facilities.
- Functionality of new RAS, proposed functional modifications, documentation of the pre- and post-modified functionality.
- The Corrective Action Plan (CAP) if RAS modifications are proposed in a CAP.
- Data to populate the RAS database:
 - RAS name.
 - Each RAS-entity and contact information.
 - Expected in-service date; most recent RC-approval and evaluation dates (or retirement date).
 - Reason for installing the RAS (*e.g., thermal overload, angular instability, poor oscillation damping, voltage instability, under- or overvoltage, or slow voltage recovery*).
 - Description of the Contingencies covered in the RAS design.
 - Action(s) to be taken by the RAS.
 - Any additional explanation relevant to high-level understanding of the RAS

Western Interconnection RAS Review

Attachment 1: Supporting Documentation for RAS Review

Functional Description and Transmission Planning Information

- Contingencies and System conditions that the RAS is intended to remedy.
- The action(s) to be taken by the RAS in response to disturbance conditions.
- A summary of technical studies demonstrating that the proposed RAS actions satisfy system performance object of its design. Shall include:
 - Study years horizon
 - System conditions
 - Analyzed contingencies
 - Date those technical studies were performed
- Information regarding any future System plans that will impact the RAS.

Western Interconnection RAS Review

Attachment 1: Supporting Documentation for RAS Review

Functional Description and Transmission Planning Information

- RAS-entity proposal and justification for limited impact designation, if applicable.
- Documentation describing the System performance resulting from the possible inadvertent operation of the RAS (except for limited impact RAS) caused by any single RAS component malfunction. Single component malfunctions in a RAS (in the category “other than limited impact”) must satisfy:
 - 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.
- An evaluation indicating that the RAS settings and operation avoid adverse interactions with other RAS, and protection and control systems.
- Identification of other affected RCs.

Western Interconnection RAS Review

Attachment 1: Supporting Documentation for RAS Review

Implementation

- Applicable equipment used for detection, dc supply, communications, transfer trip, logic processing, control actions, and monitoring.
- Detection logic and settings/parameters that control the operation of the RAS.
- Documentation showing that any multifunction device used to perform RAS function(s), in addition to other functions such as protective relaying or SCADA, does not compromise the reliability of the RAS when the device is not in service or is being maintained.
- Documentation describing the System performance resulting from a single component failure. Shows that failure will maintain the BES required performance for which the RAS was designed for.

Western Interconnection RAS Review

Attachment 2: Reliability Coordinator RAS Review Checklist

I. Design

Criteria	Meets Criteria	Notes
1. The RAS actions satisfy performance objectives for the scope of events and conditions that the RAS is intended to mitigate		
2. The designed timing of RAS operation(s) is appropriate to its BES performance objectives.		
3. The RAS arming conditions, if applicable, are appropriate to its System performance objectives.		
4. The RAS avoids adverse interactions with other RAS, and protection and control systems.		
5. The effects of RAS incorrect operation, including inadvertent operation and failure to operate, have been identified.		
6. Determination whether the RAS is limited impact. A RAS designated as limited impact 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		

Western Interconnection RAS Review

Attachment 2: Reliability Coordinator RAS Review Checklist

I. Design (Cont.)

Criteria	Meets Criteria	Notes
7. Except for limited impact RAS as determined by the RC, the possible inadvertent operation of the RAS resulting from any single RAS component malfunction satisfies all the following:		
a. The BES shall remain stable.		
b. Applicable Facility Ratings shall not be exceeded.		
c. 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.		
d. Transient voltage responses shall be within acceptable limits as established by the Transmission Planner and the Planning Coordinator		
8. The effects of future BES modifications on the design and operation of the RAS have been identified, where applicable.		

Western Interconnection RAS Review

Attachment 2: Reliability Coordinator RAS Review Checklist

II. Implementation

Criteria	Meets Criteria	Notes
1. The implementation of RAS logic appropriately correlates desired actions (outputs) with events and conditions (inputs).		
2. Except for limited impact RAS as determined by the RC, a single component failure in a RAS does not prevent the BES from meeting the same performance requirements as those required for the events and conditions for which the RAS is designed		
3. The RAS design facilitates periodic testing and maintenance.		
4. The mechanism or procedure by which the RAS is armed is clearly described and is appropriate for reliable arming and operation of the RAS for the conditions and events for which it is designed to operate.		

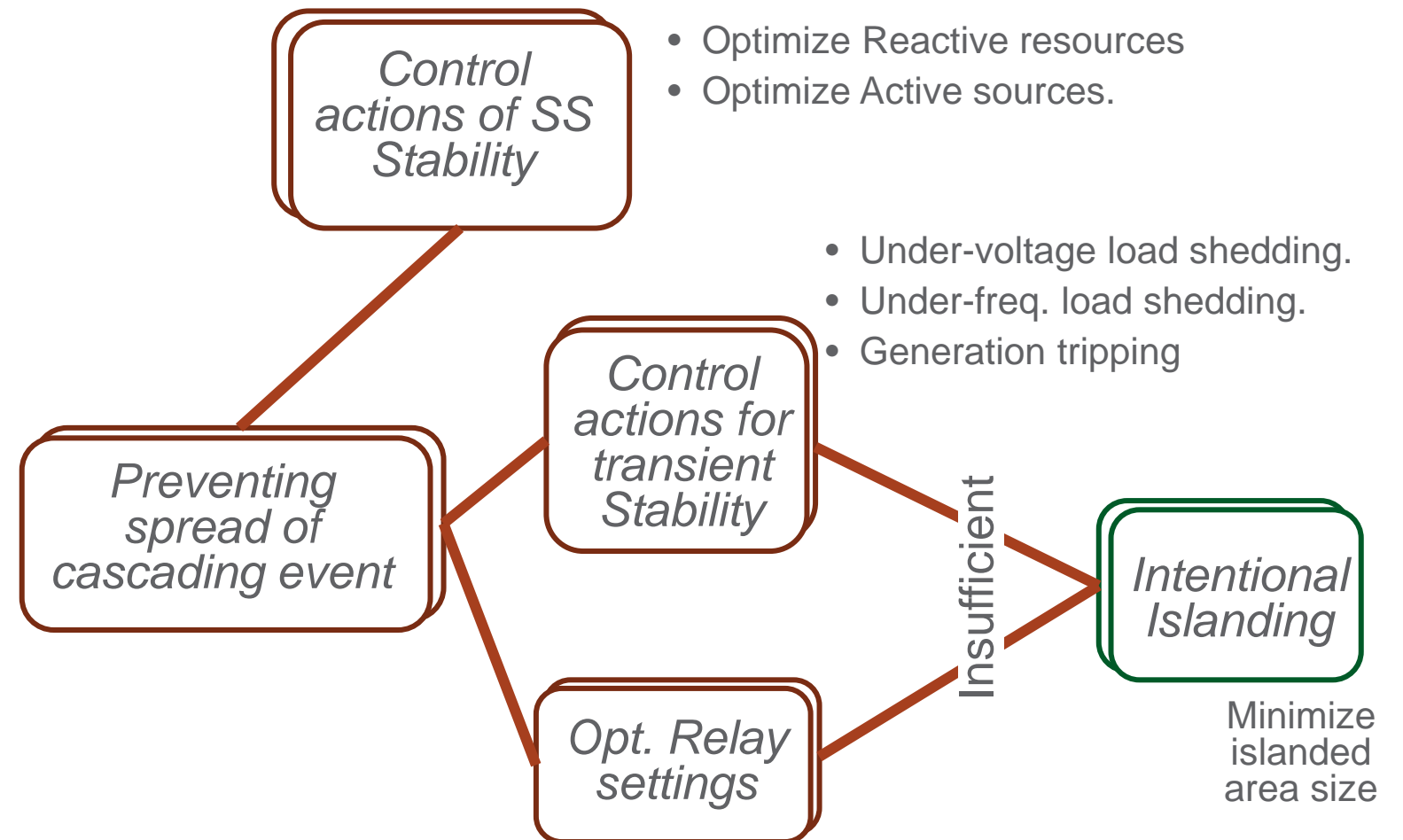
WECC – Task Effort Prevention of Cascading Outages Applications

RAS term is used by utilities in the Western part of North America and adopted by NERC.

It may be common to find System Integrity Protection System (SIPS) -IEEE and Special Protection System (SPS) - CIGRE.

Principles for mitigation:

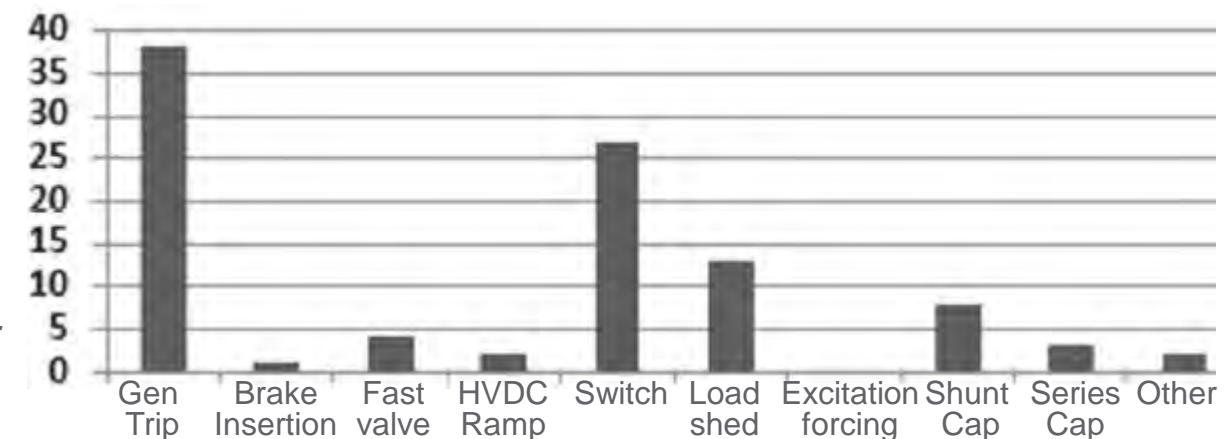
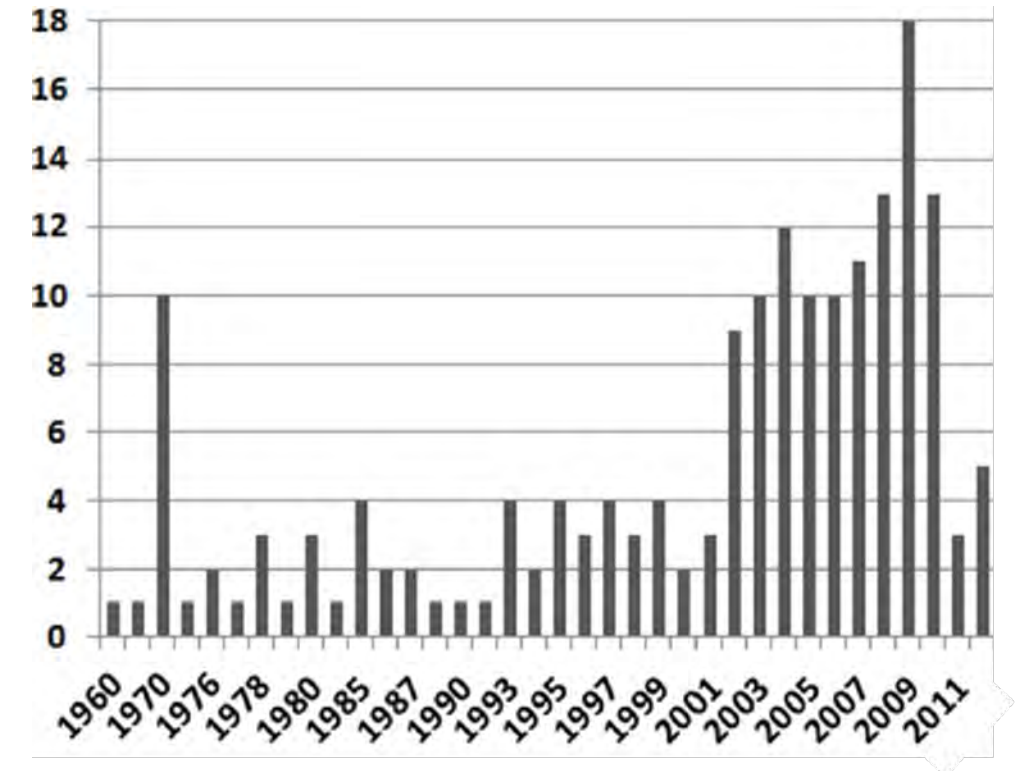
1. Identify possible initiating events, their spread, and severity.
2. Identify existing resources in the system that might be sufficient to prevent a cascading outage in planning and online environments.
3. Apply effective islanding techniques in planning and on-line environments.
4. If a blackout can't be prevented, identify an effective blackstart technique.



WECC – Task Effort Prevention of Cascading Outages Applications

WECC identifies three types of RASs, depending on their potential impact:

- Local Area Protection Scheme (LAPS) - 62% of installed RAS at WECC are LAPS
 - Wide Area Protection Scheme (WAPS) - 31% of installed RAS at WECC are WAPS
 - Safety Net (SN) - 7% of installed RAS at WECC are SN.
- **LAPS:** Used to meet an owner's performance requirements within their system. Events may result in NERC categories events 1-2 (for instance: Cat 1: System-wide voltage reduction $\geq 3\%$ during more than 15 continuous minutes due to a BPS emergency).
 - **WAPS:** Required to meet WECC performance requirements and operating standards. Events may result in NERC categories events 1-5 (for instance: Cat 3: Load or gen loss ≥ 200 MW)
 - **SN schemes:** provide defense against extensive cascading, intended to handle severe disturbances from extreme events, i.e., NERC Category 4, TPL-004 planning standard (for instance: Cat 4: Load or gen loss ≥ 5000 MW)



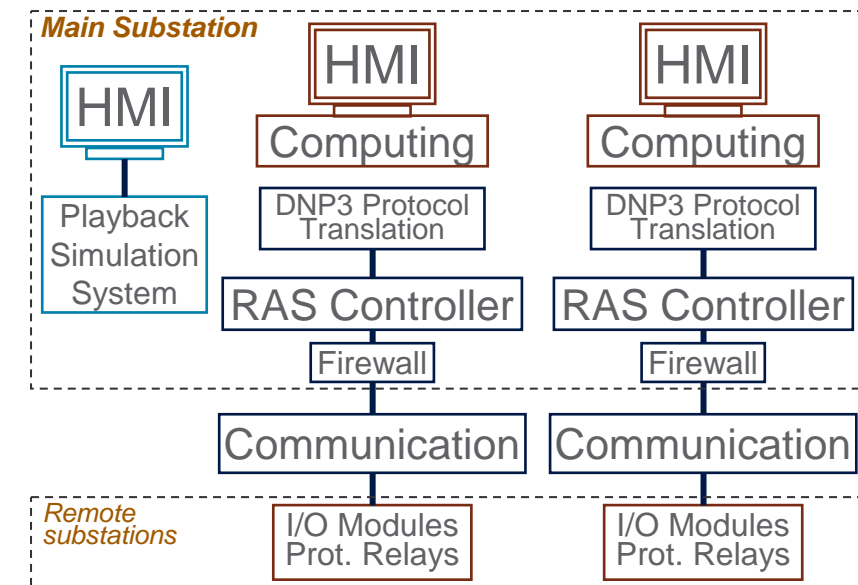
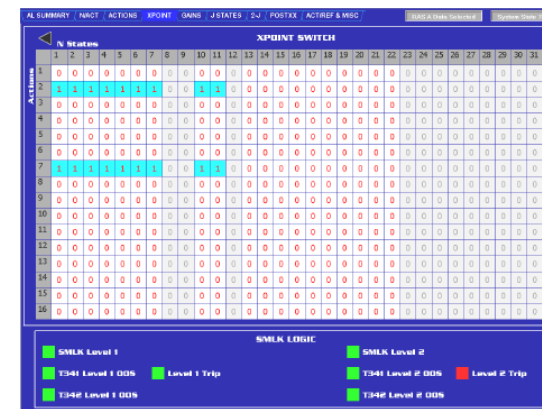
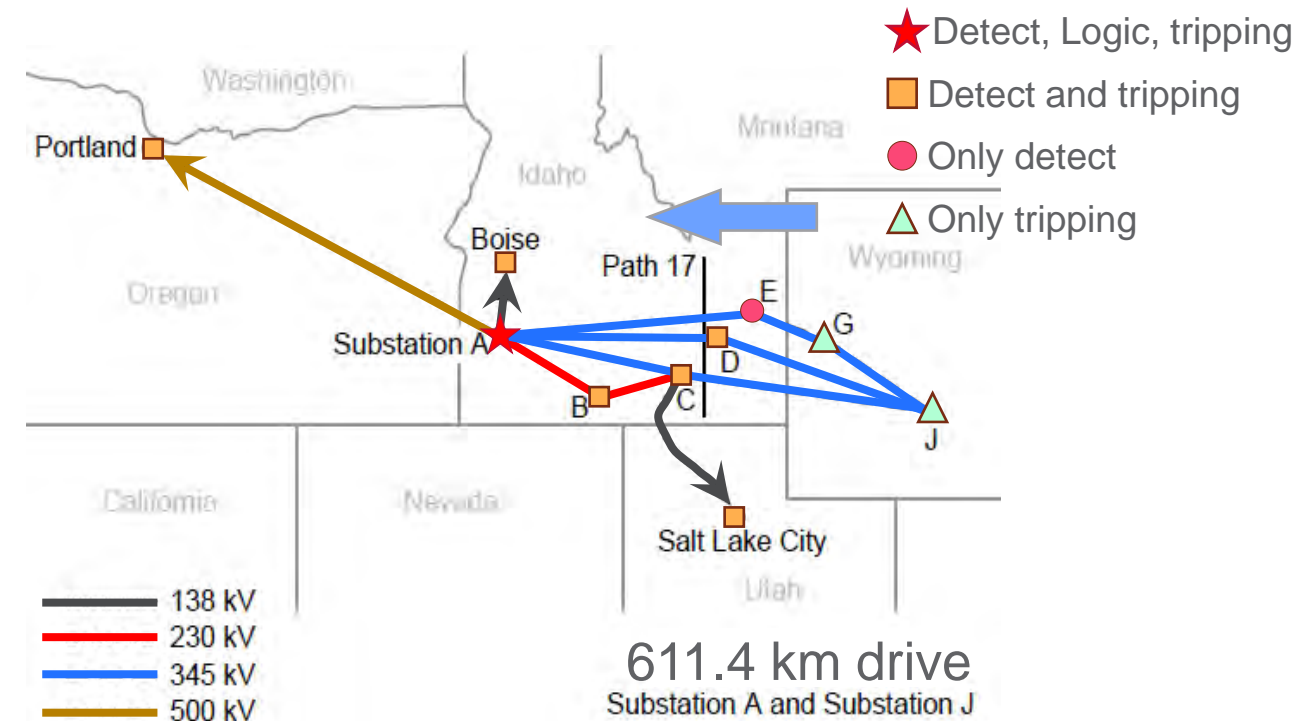
RAS Implementation Examples – IDAHO Power

IDAHO POWER RAS¹

Idaho Power Company implemented a state-of-the-art RAS to leverage transfer capability Wyoming-Oregon. RAS tripping actions are:

- Generation units.
- Bypass series capacitors.
- Insert shunt capacitors at remote substations.
- Take combination of previous actions.

Characteristics: DNP3 communication based and Dual-primary redundancy. Required response time (total throughput time) less than 20 ms.



(1) M. Vaughn, et al "Idaho Power RAS: A Dynamic Remedial Action Case Study", 2017.
https://cms-cdn.selinc.com/assets/Literature/Publications/Technical%20Papers/6433_IdahoPowerRAS_SM_20100323_Web2.pdf?v=20171206-212016

Part 2 – April 21st

- RAS Modeling Approaches for Operational Security Studies
- Deep dive on RAS modeling in PSS/E
- Application to Central America

Back-Up Slides



NERC Standard PRC-012-1

PRC-012-1: Remedial Action Scheme (RAS)

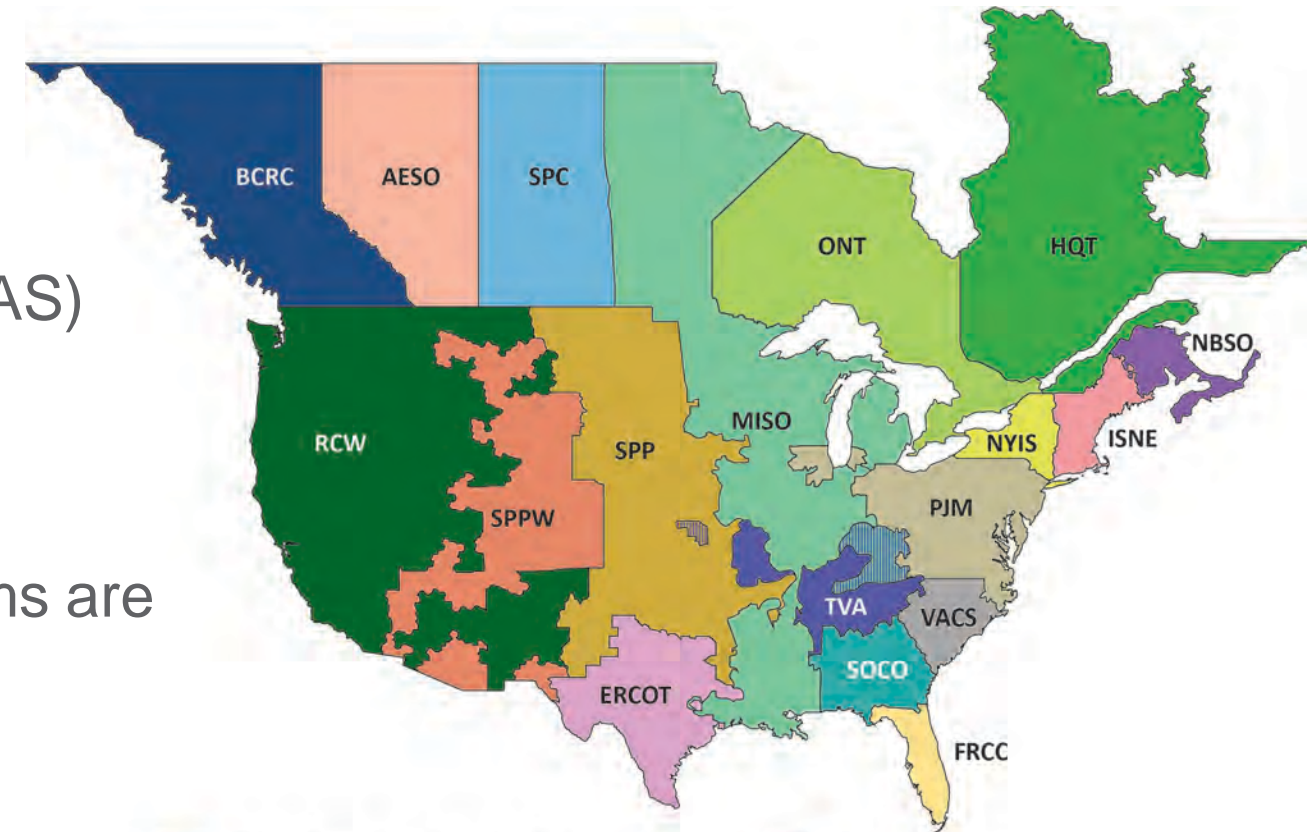
Purpose:

- To ensure that all Remedial Action Schemes (RAS) are properly designed, meet performance requirements, and are coordinated with other protection systems.
- To ensure that maintenance and testing programs are developed and misoperations are analyzed and corrected.

Applicability to:

- Regional Reliability Organization (RRO)

Two major requirements:



 Alberta Electric System Operator	 SPP West
 British Columbia Hydro	 PJM Interconnection
 Electric Reliability Council of Texas	 Reliability Coordinator West
 Florida Reliability Coordinating Council	 Saskatchewan Power Corporation
 Hydro-Quebec TransEnergie	 Southern Company Services, Inc.
 ISO New England, Inc.	 Southwest Power Pool
 Midcontinent ISO	 BAs receive RC Services from SPP or TVA
 New Brunswick Power Corporation	 Tennessee Valley Authority
 New York Independent System Operator	 BAs receive RC services from TVA or MISO
 Ontario Independent Electricity System Operator	 VACAR South

NERC Reliability Coordinators as of December 3, 2019

<https://www.nerc.com/pa/rrm/TLR/Pages/Reliability-Coordinators.aspx>

NERC Standards: PRC-012-1, PRC-012-2, and PRC-012-17

PRC-012-1: Remedial Action Scheme (RAS)

Req 1. Each RRO with a Transmission Owner, Generator Owner, or Distribution Providers that uses or is planning to use a RAS shall have a documented Regional Reliability Organization RAS review procedure to ensure that RAS comply with Regional criteria and NERC Reliability Standards.

- ✓ R1.1. Description of the process.
- ✓ R1.2. Requirements to provide data (design, operation, and modeling).
- ✓ R1.3. – 1.5 Requirements to demonstrate that RAS failure does not impact BES reliability and coordinate with protection systems (TPL standard).
- ✓ R1.6. Regional Reliability Organization definition of misoperation.
- ✓ R1.7. Documentation of corrective action plans for all RAS misoperations.
- ✓ R1.8. Identification of the RRO responsible group (procedure, process, approvals).
- ✓ R1.9. Determination, as appropriate, of maintenance and testing requirements.

Req 2.

The Regional Reliability Organization shall provide affected Regional Reliability Organizations and NERC with documentation of its RAS review procedure on request (within **30 calendar days**).

U.S. NERC Standard PRC-015-1: Remedial Action Scheme Data and Documentation

- **Purpose:** To ensure that all Remedial Action Schemes (RAS) are properly designed, meet performance requirements, and are coordinated with other protection systems. To ensure that maintenance and testing programs are developed and misoperations are analyzed and corrected.
- **Summary of Requirements:**
 - Any entity that owns a RAS:
 - ✓ shall maintain a list of and provide data for existing and proposed RAS,
 - ✓ shall have evidence it reviewed new or functionally modified RAS in accordance with the Regional Reliability Organization's procedures, and
 - ✓ shall provide documentation of RAS data and the results of studies that show compliance of new or functionally modified RAS upon request (within 30 calendar days).

U.S. NERC Standard PRC-016-1: Remedial Action Scheme Misoperations

- **Purpose:** To ensure that all Remedial Action Schemes (RAS) are properly designed, meet performance requirements, and are coordinated with other protection systems. To ensure that maintenance and testing programs are developed and misoperations are analyzed and corrected.
- **Summary of Requirements:**
 - Any entity that owns a RAS:
 - ✓ shall analyze its RAS operations and maintain a record of all misoperations in accordance with the Regional RAS review procedure,
 - ✓ shall take corrective actions to avoid future misoperations, and
 - ✓ shall provide documentation of the misoperation analyses and the corrective action plans upon request (within 90 calendar days).

U.S. NERC Standard PRC-017-1: Remedial Action Scheme Maintenance and Testing

- **Purpose:** To ensure that all Remedial Action Schemes (RAS) are properly designed, meet performance requirements, and are coordinated with other protection systems. To ensure that maintenance and testing programs are developed and misoperations are analyzed and corrected.
- **Summary of Requirements:**
 - Any entity that owns a RAS:
 - ✓ shall have a system maintenance and testing program in place, and
 - ✓ shall provide documentation of the program and its implementation upon request (within 30 calendar days).

Practices in WECC

- The Remedial Action Scheme Reliability Subcommittee (RASRS) was formed, which approves all RAS in the region before it is implemented and provides a uniform review process evaluating reliability.
- The RAS Modeling and Verification Task Force (RMVTF) was formed and conducted a survey used to develop a common practice for modeling RAS in the region.
- WECC now maintains a set of remedial action scheme models, which can then be leveraged when running contingency analysis and system studies in the region.