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Adaptive RAS/SPS System Settings for Improving Grid Reliability and Asset Utilization through Predictive Simulation and Controls

Task 1 Report – Survey on RAS/SPS modeling practice

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Abstract

Remedial Action Schemes (RAS) or Special Protection Schemes (SPS) are used throughout the bulk transmission system as a non-wires method of increasing transmission transfer capability. However, as the population grows within the Western Interconnection, more power needs to be transferred with less ability to build lines. This leads to a greater number of RAS, and the subsequent interaction between these disparate schemes can have unintended consequences.

While the large number of RAS within the Western Electricity Coordinating Council (WECC) protect for different things, which can range from the violation of thermal limitations to transient stability issues, they can be described by common methods of operation. In order to understand these methods, a survey was sent out to members of the WECC Modeling & Validation Working Group (MVWG). The response received provides a necessary base in which to understand and build models that can be used within WECC.

This report provides information on the survey results regarding RAS/SPS modeling practices for planning and operational studies within the WECC footprint, which is foundational for on-going and future work on RAS. Pacific Northwest National Laboratory (PNNL) and its industry partners are developing innovative methods for adaptively setting RAS parameters based on realistic and near real-time operational conditions to improve power grid reliability and grid asset utilization.

Summary

A survey was conducted on RAS within the WECC footprint to develop a comprehensive understanding of RAS operating within the system as well as how these RAS are modeled within software. Establishing this situational awareness is foundational to work moving forward as PNNL collaborates with PacifiCorp and Idaho Power Company to develop innovative methods for RAS modeling and adapative parameter settings.

This report provides a summary of these survey results, including the classification of these RAS based on their objective, action and initiating condition. One key finding of this survey is that most modeling practices involve manually defining the RAS within the contingency definition based on pre-determined actions. This can create discrepancies between how RAS operates within the system and how it is modeled.

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We also would like to thank all the survey participants within the WECC footprint.

Acronyms and Abbreviations

WECC	Western Electricity Coordinating Council
BPA	Bonneville Power Administration
EMS	Energy Management System
FERC	Federal Energy Regulatory Commission
RAS	Remedial Action Scheme
SPS	Special Protection Scheme
MVWG	Modeling and Validation Working Group
NERC	North American Electric Reliability Corporation
RMVTF	RAS Modeling and Validation Task Force
MSRATF	Modeling Special Protection and Relay AdHoc taskforce
LLL	Line Loss Logic
CTG	Contingency

Contents

1.0 Background

The North American Electric Reliability Corporation (NERC) Glossary of Terms [1] defines a Remedial Action Scheme as:

> *"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)."*

It goes on to stipulate that the objectives of a RAS may be to meet reliability standards, maintain the stability of the bulk electric system, maintain system voltages or acceptable power flows, and/or reduce the impacts of extreme events. A successfully implemented RAS will increase the transfer capability of the transmission system by preventing and resolving system violations under a pre-determined set of conditions. However, as more RAS are added to the system, interactions between RAS can have unintended consequences as in the case of the massive blackout in the Pacific Southwest on September 8, 2011 [2]. This is further complicated as new technologies, such as the increased penetration of renewables, change power flow patterns and introduce new stochastic dynamic behaviors.

In WECC, all RAS must be approved by the WECC Remedial Action Scheme Reliability Subcommittee (RASRS), which provides a uniform review process evaluating the reliability aspects of RAS in order to enhance grid performance [3]. However, anticipating the potential results of the intearactions between these RAS under all possible system conditions and contingencies presents serious challenges. Specifically, developing a comprehensive understanding of how RAS will behave requires a holistic and dynamic approach to RAS modeling and the ability to simulate a massive number of contingencies and scenarios.

This report provides a survey of existing RAS and how they are modeled within the WECC footprint, which will serve as a foundation for addressing some of these challenges moving forward and developing an innovative approach for adaptively calculating RAS settings in near real-time to improve RAS performance.

2.0 Objective of the Survey

The objective of this survey was to garner a comprehensive understanding of the types of RAS implemented within WECC as well as to establish common practices regarding how these RAS are modeled. This work is foundational to future work in developing new, innovative RAS modeling and optimization techniques.

3.0 Survey Contents

The survey sought to gather the following information on the RAS within the WECC footprint in order to characterize the types of RAS being deployed within the region and to better understand how these schemes are modeled. The key information required from the WECC entities includes the following items:

1. **Software** – The type of software used to perform power system analysis.

2. **Objective** –The purpose of the RAS, specifically what the RAS is intended to protect against.

3. **Remedial Actions** – The corrective actions taken.

4. **Arming Criteria** – The monitored topology or system conditions used to set the arming levels for RAS implementation.

5. **Initiating Conditions** – The monitored topology or system conditions that trigger the RAS to operate.

6. **Modeling Method** – How the RAS is modeled in the software, including whether the RAS leverages existing software tools and whether transient analysis is performed.

4.0 Survey Results

Due to the sensitive nature of critical energy/electric infrastructure information (CEII), the survey results had to be genericized prior to publication. To this end, the findings of this survey have been distilled to four anonymous utilities. Each entity that participated in the survey has reviewed these summary results and confirmed that the generic representations are valid and appropriate.

4.1 Key Findings

1. When applicable, the arming criteria for almost all RAS operations depend upon system conditions rather than changes to system topology.

2. Most RAS trigger upon changes to system topology, with very few being initiated by changes to system conditions.

3. Most modeling practices involve manually defining the RAS within a contingency definition based using pre-determined actions.

4.2 Generalized Survey Results

<u>Utility 1:</u>

RAS 1:
<u>Software:</u> PowerWorld Simulator
<u>Objective</u>: Prevent loss of synchronism
<u>Remedial Actions</u>: Trip generator(s) offline
<u>Arming Criteria</u>: Measured generation power output
<u>Initiating Condition</u>: Line loss logic
<u>Description:</u> When generator output is greater than a set of pre-determined conditions and a line is lost from the system, generation will be tripped in order to prevent loss of synchronism.
<u>Modeling Method:</u>

- Powerflow: Modeled in WECC RAS & contingency (CTG) format using built-in RAS tools
- Transient: Included in the contingency definition

<u>Utility 2</u>

RAS 1:
<u>Software:</u> PSS®E and custom Python software, PowerWorld Simulator
<u>Objective</u>: Prevent line or transformer overloading
<u>Remedial Actions</u>: Take generators and/or lines out of service
<u>Arming Criteria</u>: Path flows
<u>Initiating Condition</u>: Line loss logic
<u>Description:</u> If flows on a path are greater than a set of pre-determined conditions and a line affecting that path is lost, generation will be tripped and/or other lines in the system will be opened to reduce path flows and prevent overloading.
<u>Modeling Method:</u>

- PTI:
  - Powerflow: Manually implemented if overloads are present in the solution.
  - Transient: A custom Python tool checks pre-contingency flows and will arm/disarm RAS if it meets the criteria.
- PowerWorld:
  - Powerflow: Modeled in WECC RAS & CTG format using built-in RAS tools
  - Transient: Included in the contingency definition (one with RAS, and one without)

RAS 2:
<u>Software:</u> PSS®E and custom Python software, PowerWorld Simulator
<u>Objective:</u> Prevent damage to generators that could be caused by events on the system
<u>Remedial Actions:</u> Trip generator(s) offline
<u>Arming Criteria</u>: None
<u>Initiating Condition:</u> Generator accelerates more than a predetermined threshold
<u>Description:</u> Upon sensed acceleration of the generator shaft due to a system event, the generation units will be tripped offline.
<u>Modeling Method:</u>

- PTI:
  - Powerflow: Results for transients used
  - Transient: Iterative solution between custom C program and PTI transients
- PowerWorld:
  - Powerflow: Results from transients used
  - Transient: model defined within the program

Utility 3

RAS 1:

Software: PowerWorld Simulator
Objective: Prevent thermal overloads of monitored lines or transformers
Remedial Actions: Open lines or transformers
Arming Criteria: Current flow through a line or transformer exceeds a predetermined threshold
Initiating Conditions: Time elapsed since meeting arming criteria
Description: Overcurrent relay detects current flow through the line or transformer and will open it after a defined time period when the current exceeds the specified threshold.
Modeling Method:

- Powerflow: Modeled in WECC RAS & CTG format using built-in RAS tools
- Transient: The time frames for the operation of these relays would not typically occur within the typical transient time frame.

RAS 2:

Software: PowerWorld Simulator
Objective: Prevent thermal overloads of monitored elements
Remedial Actions: Reduce generation output
Arming Criteria: Current flow through a line or transformer exceeds a predetermined threshold
Initiating Conditions: Time elapsed since meeting arming criteria
Description: Overcurrent relay detects current flow through an element and will adjust generation output after a defined time period when current exceeds the specified threshold.
Modeling Method:

- Powerflow: Modeled in WECC RAS & CTG format using built-in RAS tools
- Transient: This RAS has not yet been studied in transient stability studies. Time delay overcurrent relay dynamic models have been populated though they tend to operate outside of the transient study timeframe studied by the utility.

Utility 4

RAS 1:

Software: PowerWorld Simulator, GE PSLF
Objective: Prevent line or transformer overloading and voltage instability
Remedial Actions: Trip generator(s) offline
Arming Criteria: Path flow
Initiating Conditions: Line loss logic
Description: Generation is tripped in order to prevent overloads/voltage instability caused by line outages. The amount of generation to be tripped depends upon the measured path flow.
Modeling Method:

- PSLF:
    - Powerflow: Not typically used for steady state analysis
    - Transient: Included in the contingency definition
- PowerWorld:
    - Powerflow: Modeled in WECC RAS & CTG format using built-in RAS tools
    - Transient: Included in the contingency definition

RAS 2:

Software: PowerWorld Simulator, GE PSLF
Objective: Maintain voltage stability
Remedial Actions: Reconfigure shunt and series devices to provide reactive power support
Arming Criteria: Bus voltage
Initiating Conditions: Time elapsed since meeting arming criteria

Description: Depending on the monitored bus voltage levels, time delays are set and remedial actions are determined. The subsequent actions are taken iteratively until either the RAS threshold for operation is no longer met or all possible device reconfigurations have been exhausted.
Modeling Method:

- PSLF:
  - Powerflow: Not typically used for steady state analysis
  - Transient: A user defined model is used (custom EPCL)
- PowerWorld:
  - Powerflow: Due to the fast action of this RAS, it is typically modeled as part of a contingency based upon the transient response.
  - Transient: A defined model already included in the program

5.0 Interpretation of Survey Results

A discrepancy emerges from this survey between how RAS works and how it is modeled. It is important to note that a majority of RAS implementations within the transient simulation are included within the contingency itself. This can be problematic in that while a contingency can affect system topology, it cannot proactively impact system conditions based on the current system state. As a result, the modeled RAS may not be armed appropriately based on system conditions and therefore may not perform appropriately within the simulation. Figures 1 and 2 illustrate the key differences between how RAS is modeled and how RAS exists within the power system.

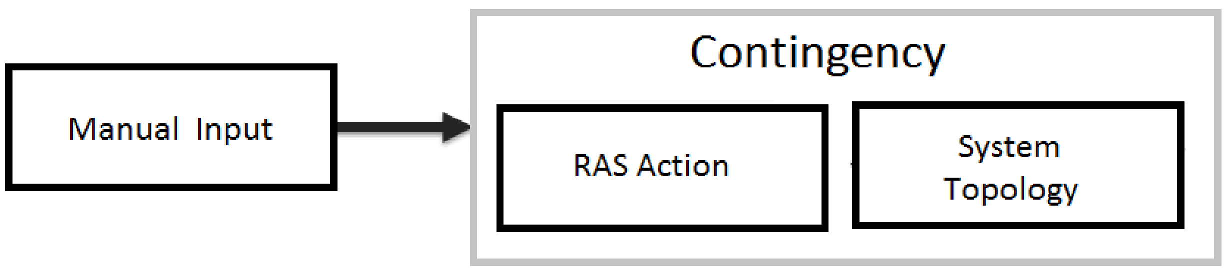

Figure 1: Block Representation of Current RAS Modeling

When RAS is modeled, the RAS arming and system conditions are often manually determined and then included within the contingency definition. The contingency, or the event to be analyzed in the software analysis, causes pre-determined topology changes, which then initiates pre-determined remedial actions. This method is then used to evaluate the RAS. However, because the RAS actions are pre-determined, this method precludes the dynamic arming of the RAS within the model based on system conditions

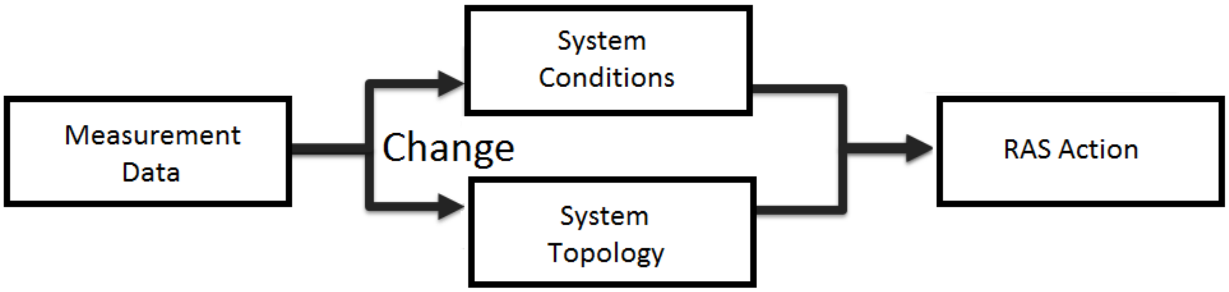

Figure 2: Block Representation of Actual RAS Operation

When RAS operates in the actual power system, real-time power system data is used to arm the RAS (where applicable), which dictates how and when remedial actions are taken. In some less common cases, monitored system conditions will even be the initiating condition that triggers the RAS. This is impossible to model within a contingency, which is solely defined by a pre-determined topology change. This often creates an inherent disconnect between how RAS is modeled and how it will operate the actual power system, which can lead to unintended and unanticipated consequences, particularly in the way that different RAS interact. While this generalization is not universally applicable across RAS, it is an important consideration in understanding and baselining RAS across the system.

6.0 Next Steps

Developing this survey report is the first task in a larger project, the goal of which is to develop innovative methods for adaptively setting RAS parameters based on realistic and near real-time operational conditions to improve power grid reliability and grid asset utilization. The PNNL team is collaborating with PacifiCorp and Idaho Power Company to fully understand the details of the RAS modeling practices being used for planning and operational purposes, and to develop new approaches that leverage high-performance-computing (HPC) techniques.

Under the second task of this project, the PNNL team will identify a selection of RAS examples and summarize their operational logic and arming criteria. The team will also evaluate the candidate RAS, Jim Bridger, and investigate how arming levels are affected by transient stability simulation results under different operating conditions. New solutions will be explored to reduce complexity while maintaining reliability. A second report will be developed documenting this work.

Moving forward, the team will develop adaptive algorithms for RAS arming using HPC techniques, develop a prototype implementation of the algorithm using commercial software tools and demonstrate that prototype.

7.0 Bibliography

[1] North American Electric Reliability Corporation, "Glossary of Terms Used in NERC Reliability Standards," 2017.

[2] Federal Energy Regulatory Commission and the North American Electric Reliability Corporation, "Arizona-Southern California Outages on September 8, 2011: Causes and Recommendations," 2012.

[3] Western Electricity Coordinating Council, "Remedial Action Scheme Reliability Subcommittee," Accessed on 25 October 2017. [Online]. Available: https://www.wecc.biz/OC/Pages/RASRS.aspx.

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