Data-driven Approach and Potential Cloud Application in Power System RAS Studies

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Control is the ultimate step... where the action occurs to optimize energy system performance

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.
Remedial action scheme (RAS) is

- Designed to sense abnormal conditions and take corrective control actions to improve grid reliability and resilience.
- One of the most important alternative control option in operation, besides the traditional power system controllers, e.g., exciters, governors, PSS, etc.;
- Required to be properly designed and accurately modeled for power system compliance studies.

HOWEVER, technical gaps are identified in the RAS settings in today’s practice.

- Most settings are determined offline;
- Only assume the “worst” operating condition and some critical contingencies;
- Very conservative performance, leading to asset under-utilization;
- Sometimes risky and may cause reliability issues, when encountering unstudied conditions.

Figure 3. WECC Remedial Action Scheme review process. Owner responsibilities are color coded in yellow and WECC responsibilities in blue. Source: WECC Guideline for Procedure and Information Required for RAS assessment. https://www.wecc.biz/Administrative/10a%20Procedure%20and%20Information%20Required%20for%20RAS%20Assessment.pdf
Ongoing DOE project: Adaptive RAS/SPS System Settings for Improving Grid Reliability and Asset Utilization through Predictive Simulation and Controls

Main Objective
- To develop innovative mathematical and advanced computing methods for adaptively setting RAS/SPS parameters based on realistic and near real-time operation conditions, powered by HPC.

Resources
- Abundant expertise in power grid modeling and simulation;
- Dedicated industry support from Western Utility collaborators with details of active RAS models as well as multi-year data;
- HPC/Cloud platforms and commercial packages for high-fidelity simulations.

Deliverables
- Prototype design and development in commercial platform;
- Technical report and research publications.

Figure 4. An illustration of “ABCDE” design concept for transformative remedial action scheme tool (TRAST).
Supporting AGM Program Vision and Goals

OE’s Advanced Modeling Grid Research Program objectives [1] are to:

- Support the transformation of data to enable preventative actions, rather than reactive responses to changes in grid conditions;
- Direct the research and development of advanced computational and control technologies to improve the reliability, resiliency, security, and flexibility of the nation’s electricity system;
- Help system operators and utilities prevent blackouts and improve reliability by expanding wide-area real-time visibility into the conditions of the grid;
- Support improvement of the performance of modeling tools and computations that are the basis of the grid operations and planning; and
- Support the tracking and expansion of the use of quantitative risk and uncertainty methods by federal and state level energy system decision makers regarding energy infrastructure investments.

DOE RAS project directly supports AGM program vision and goals, by:

- Developing innovative mathematical methods for determining RAS parameters in near real-time;
- Enhancing RAS modeling accuracy and, therefore, system resilience following severe disturbances;
- Building software prototypes for automating study procedures;
- Leveraging high-performance computing techniques to achieve speed gain.

Overview of Transformative RAS Tool (TRAST)

Figure 5. Overview of Data-driven analytical functionalities in TRAST [2].

Utility Data Interface in TRAST

2017 WECC planning cases
Heavy summer/spring

2016-2018 WECC Path SCADA data

2017 Peak RC SE Cases

Base Cases
Path stress patterns
EMS Cases

Realistic Scenario Generation

S State
N Event

Massive Simulations (HPC)

Dynamic models and parameters
RAS models

Contingency definition

New algorithms for calculating RAS settings in near real time

System status
Arming Levels for (S,N) pair

Validation of RAS settings

Pass

Fail

RAS Coefficient

Adaptive RAS/SPS settings for operation

Validated RAS Coefficient

: Synthesized data/cases
: Data/Cases from IPC, PacifiCorp & Peak
: RAS model design (PacifiCorp)
: RAS event record (PacifiCorp)

Figure 6. Overview of Utility data interface in TRAST [2].

Utility Data Analysis for RAS in TRAST
Topic 1: Which data? How long?

- Utility Data type:
  - Power plant total generation;
  - Transmission path power flow;
  - Equipment status.

- Utility Data Time scale:
  - Seconds;
  - Minutes;
  - 10s of Minutes;
  - Days-Years.

*As of June 30, 2014
Source: EIA

Figure 7. An illustration of WECC Balancing areas. Source: EIA. https://www.rtoinsider.com/caiso-cost-allocation-plan-balancing-area-27454/

Figure 8. An illustration of electricity grid. Wikipedia, Own work Originally derived from de:Datei:Stromversorgung.png, CC BY 3.0.
Utility Data Analysis for RAS in TRAST
Topic 2: Review data in existing RAS design

- Time period of study:
  12/01/2016 0:00 – 04/30/2018 23:30.

- Measurements are recorded and pre-processed at a 30-min resolution, with a total of 24768 data points for each variable.

- The following 7 variables are included:
  - Gen is the power plant real power generation;
  - Path1 is the first WECC path real power flow;
  - Path2 is the second WECC path real power flow;
  - Path3 is the first internal path real power flow;
  - Path4 is the second internal path real power flow;
  - Gvar is the power plant reactive power generation;
  - AvaiComp is one equipment status indicator.

![Normalized utility data visualization](image)

Figure 9. Normalized utility data visualization (top) and initial analysis by season (bottom).
Utility Data Analysis for RAS in TRAST
Topic 2: Review data in existing RAS design (Cont’)

**Conclusion:** Correlation exists between current RAS input data.

**Recommendation:** Dimension reduction can be performed for the original RAS input data.

![Pairwise correlation coefficients of all seven variables.](image)

**Figure 10.** Pairwise correlation coefficients of all seven variables.

**Figure 11.** Scatter plot between Gen and Path 1 (top) and box plots between path 1 and AvailComp (bottom).
Utility Data Analysis for RAS in TRAST
Topic 3: How data analysis benefits the RAS analysis?

Smart sampling for automated utility planning case generation

► Originates from 2017 full year’s SCADA data: 01/01/2017 00:00 – 12/31/2017 23:30, in total 17520 data points for each variable.

► The objectives:
  ■ For each variable, represent the probability distribution according to the original data using much fewer samples;
  ■ Consider the data-dependency among the variables.

► Solution:
  Customized Latin Hypercube Sampling (LHS)
  ■ Resolved unknown PDF issues;
  ■ Account for original correlation with Cholesky decomposition.

► Results:
  ■ A list of 365 sampled points to guide automated utility planning case generation in TRAST;
  ■ Significantly reduce the dynamic simulation efforts.
The project team at PNNL has received the first batch of data from Peak Reliability (about 10,000+ EMS SE cases in PTI RAW V30 format). They are the West-wide-System-Model snapshot exported from the State Estimator (SE) of Peak’s energy management system (EMS). The detailed information for the received data is given as follows:

- 2017 Full Year SE exported snapshot
  - 1-hour resolution;
  - There are in total 9374 cases.

- Four events related SE cases in 2016
  - 24-hour range;
  - 5-minute resolution;
  - 300 cases per event;
  - Proposed by PacifiCorp, each contains the correct operation of Jim Bridger RAS and detailed record of system conditions.

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**Figure 16. Original Data plots for Peak SE extracted data in Event 2, 3, 4.**

**Figure 17. Original Data plots for utility SCADA data in Event 2, 3, 4.**
TRAST: A comprehensive tool for RAS studies

• RAS design and logic needs to be assessed through comprehensive studies [3]:
  ▪ Study Years;
  ▪ System Conditions;
  ▪ Contingencies analyzed;
    ✓ N-1;
    ✓ N-1-1;
    ✓ N-2;
    ✓ Extreme;

• The RAS assessment is time-consuming and labor-burdened, not even mentioning the RAS design and validation process before submitting to WECC RASRS.

• Transformative RAS Tool (TRAST) enables a statistical and efficient way to identify a list of appropriate scenarios to represent the system conditions of utility study interests:
  ▪ 2017 SCADA data including 17520 vectors is sampled into 365 vectors;
  ▪ Automated utility planning case generation provides a powerful, yet flexible, way for generating a reasonable case pool for RAS studies;
  ▪ The unified fault model for multi-section line enables a clear and accurate interface for dynamic simulations;
  ▪ For the targeted RAS in our project, there are roughly about 365*648*33 ≈ 7.8 million dynamic simulations to be evaluated.

• TRAST provides an systematic and automated/semi-automated solution for RAS validation and assessment.
  ▪ Parallel computing in Cloud environment;
  ▪ Machine Learning tool assisted control feature analysis and selection.

Cloud Application in Power System RAS Studies

- Python script drafting on personal laptop: 1-Core
- Parallel Computing on personal laptop: 8-Core
- Parallel Computing on EIOC Server: 32-Core
- Parallel Computing on Cloud Server: 72-Core Multi-node

Personal Laptop: 8 Cores
PNNL EIOC Server: 32 Cores (on premise)
PNNL Cloud Server: 72 Cores (Microsoft Azure)
PNNL Cloud Application Snapshot

- Entrance: https://portal.azure.com
- Three servers were configured, two to be added soon
- Metered by usage, economical and quickly deployment
Concerns on Cloud Security?

- PNNL takes the safety and security of the environments we create and operate on your behalf seriously. In an effort to ensure that all PNNL cloud accounts are appropriately instantiated, managed, and operated, we recently stood up a Cloud Computing office. In addition to securing our cloud environments (compliant to NIST 800-53), they have a charter to support and educate staff on cloud best practices. We are partially funding this activity through an additional levy on projects that utilize cloud services. These additional funds enable us to bring enterprise-level tools to bear across our entire portfolio of cloud environments so we can quickly and effectively apply security controls to keep your applications and data safe. If you have any questions about our approach to cloud security, please feel free to reach out to the Cloud Computing office directly at cco@pnnl.gov, or through your PNNL project manager.
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