



Hydropower Fleet Intelligence (HFI)

1.4.1.506

Hydropower Program

10/10/2019

Principal Investigator:
Stephen Signore

Organization: ORNL

Project Summary

- Addresses the challenges of making data-driven decisions for hydropower assets.
- Incorporates evolving contexts for hydropower operations and maintenance—increasing renewables, increasing dispatch variability, increasing constraints on operations
- Recognizes that data-driven decision-making requires efficient and automated processes for acquiring, qualifying, archiving, analyzing, and sharing hydropower data and results.

Project Objective & Impact

- Enhance and coordinate existing but disparate cost, condition, and reliability data sets available within the hydropower industry to inform decision-making and improve hydropower value and reliability.
- Demonstrate how use-case, metric-based, data-driven decision-making can enhance hydropower asset management outcomes, beginning with a use-case of a utility-owned hydropower facility responding to increasing dispatch variability from solar and wind growth within a balancing authority.

Project Information

Project Principal Investigator(s)

Stephen Signore
Brennan Smith

WPTO Lead

Mark Christian

Project Partners/Subs

Signal Hydropower Consultants
CEATI International
Electric Utility Cost Group
Pacific Gas & Electric

Project Duration

Project Start Date: October 2018
Project End Date: September 2020

Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

Technology R&D for
Low-Impact
Hydropower Growth

R&D to Support
Modernization,
Upgrades and Security
for Existing Hydropower
Fleet

Understand, Enable,
and Improve
Hydropower's
Contributions to Grid
Reliability, Resilience,
and Integration

R&D to Support Modernization, Upgrades, and Security for Existing Hydropower Fleet

- Create mechanisms to classify diverse hydropower plants by mechanical and cyber-physical systems, providing better characterization of the fleet and allowing identification of exemplary facilities / practices
- Advanced instrumentation and data evaluation to improve equipment longevity and condition based repair

- ORNL's HFI team has synthesized hydropower facility, unit, and component physical taxonomies and data formats from multiple industry data consortia—necessary for future sharing and comparing of hydropower asset management data, metrics, and performance.
- The *HFI Foundational Concepts Report* provides a reference for hydropower O&M concepts, configuration parameter definitions, physical equipment hierarchies, and metrics definitions and computation algorithms needed for sharing and comparing of hydropower asset management data, metrics, and performance.
- The ORNL HFI team prepares the annual EUCG benchmarking report that analyzes cost data and identifies top performing hydropower asset owners and the O&M best practices that enable that performance.
- A research partnership between ORNL and PG&E is demonstrating *HFI Use Case 1 – Detecting the O&M Impacts of Increasing Dispatch Variability* using the Helms Pumped-Storage Facility as a test case.

Big-Data Access and Analysis

- Help industry to manage large, disparate and dissimilar datasets relevant for performance, operations, costs, maintenance, permitting, and environmental mitigation

ORNL's HFI team works with the leadership of three industry consortia to coordinate and enhance fleet-wide data sets:

- **Electric Utility Cost Group (EUCG):** ORNL HFI data analytics help EUCG leadership and members benchmark operation and maintenance (O&M) costs and identify top performers and O&M best practices.
- **Generation Availability Data System (GADS):** ORNL HFI data analytics reveal the limits of incomplete hydropower configuration data and lack of specificity in hydropower asset outage reporting in GADS. ORNL is helping GADS-NERC leadership to draft improved reporting guidance that will address these shortcomings.
- **Hydropower Asset Management Partnership (hydroAMP):** ORNL HFI data analytics help the hydroAMP Steering Committee identify gaps in hydropower condition assessment data. ORNL is assisting the Steering Committee with data portal development and the implementation of an 18-point plan to improve data quality, increase the usefulness of the database for members, and increase membership through demonstrated improvements to breadth, depth, and quality of data.
- **Fleet-wide correlation:** ORNL work to link these data and respect data confidentiality will enable unprecedented fleet-wide and peer group analyses of correlations between cost, equipment condition, and reliability.

Hydropower asset managers can produce more value and reliability with their decisions when they have better data and correlation information for their facilities and peer groups.

Project Budget

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget FY17–FY19 Q1 & Q2 (October 2016 – March 2019)	
Costed	Costed	Costed	Total Costed	Total Authorized
[\$0K]	[\$599,163]	[\$169,746]	[\$768,909]	[\$894,890]

Benchmarking

- Annual EUCG cost report
- EUCG top performers methodology rework
- hydroAMP data sufficiency report
- hydroAMP data improvement plan
- NERC GADS data assessment

Data Analytics

- Foundational Concepts
- Use-case development including summary and specification documents
- Identifying PG&E as a partnering utility
- Data Classification and Sufficiency Report

Database Development:

- Coordination with HydroSource and Existing Hydropower Assets
- Mapping of unique identifiers from industry databases

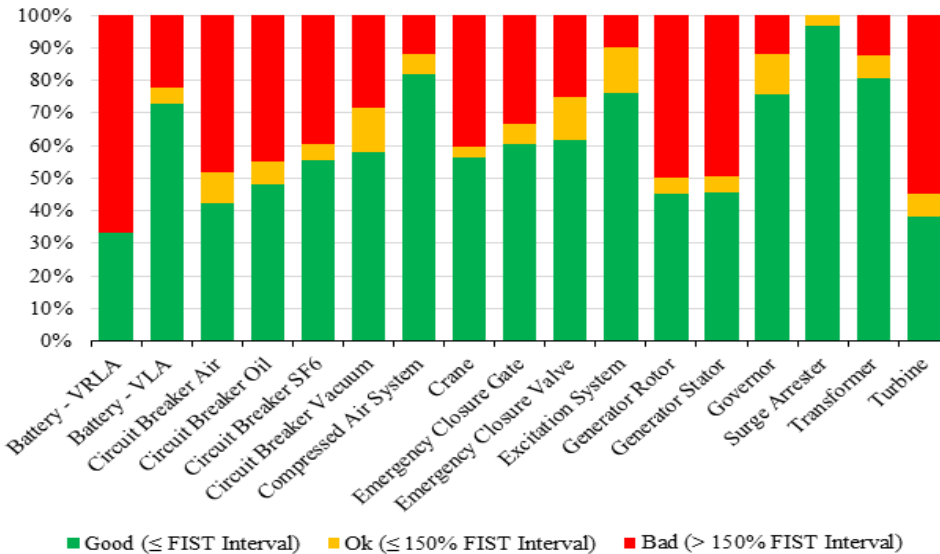
- **Express value of quality data**
 - Participation in industry consortia
 - CEATI HPLIG and AMIG
 - EUCG – Hydroelectric Productivity Committee
 - NERC GADS working group
- **Disseminate pertinent findings**
 - CEATI Fall Asset Management conference
 - EUCG workshops
 - Public Reports
- **Disseminate new analytical methods**
 - *ASCE Journal of Uncertainty and Risk Analysis*
 - *The Effect of Parameter Uncertainty on Hydropower Asset Replacement Cost Models*
 - *Whole Life Cost Model role in Capital Investment Strategies*
 - *Conference Presentations*
 - CEATI AMIG
 - IEEE PMAPS
 - HydroVienna

- **hydroAMP 2018 Assessment Report**
 - Elucidate key areas for data improvement concerning depth, breadth, and completeness before rich data analytics can occur
- **EUCG 2017 and 2018 Annual Cost Reports**
 - Harmonization of cost categories
 - Top performers analysis identifies workshop topics
 - Cost benchmarking shows industry trends
- **NERC GADS 2018 Assessment Report**
 - Prompted discussion with GADS working group on design data changes

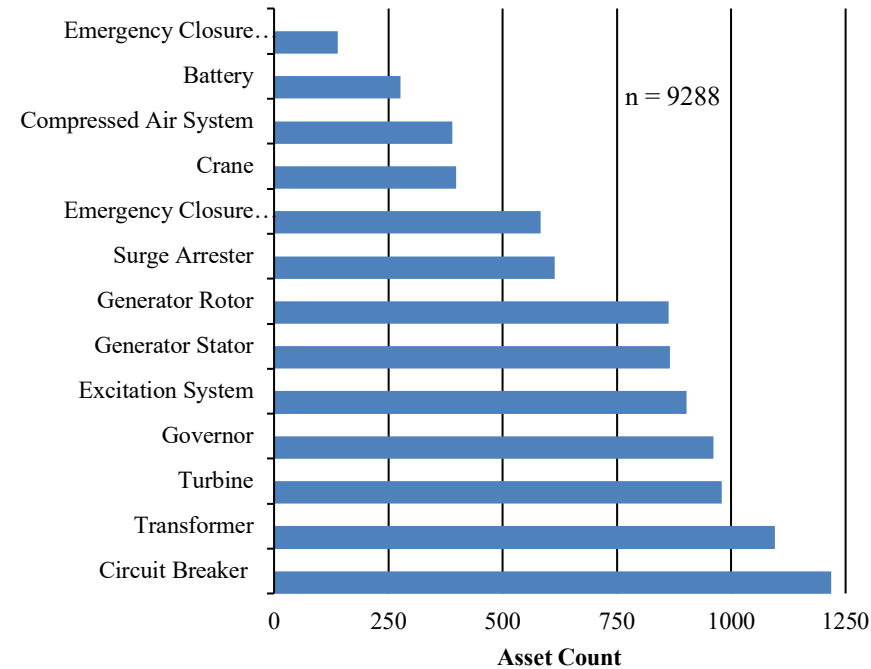
- **Foundational Concepts Report**
 - Clarity, transparency and provenance of data and analytical methodologies
- **Conference papers (2) on powertrain reliability models**
 - Unit dispatch preferences in terms of reliability impact
 - Not impacted by mode of operation, capacity factor, environmental flows, etc
- **Journal manuscripts (2) submitted on whole life cost models**
 - Understanding uncertainty in decision making models
 - Cost estimations are more impactful than failure distribution estimates

HFI analysis of hydroAMP condition assessment data quality

HydroAMP Profile 2017: Asset Freshness per FIST Standards
All Utilities



HydroAMP Profile 2017: Asset Distribution



Are the hydroAMP data current? How often are component condition scores, on-average, in the hydroAMP database updated compared to the recommended maintenance intervals in the Bureau of Reclamation Facilities Instructions, Standards and Techniques (FIST) Manuals?

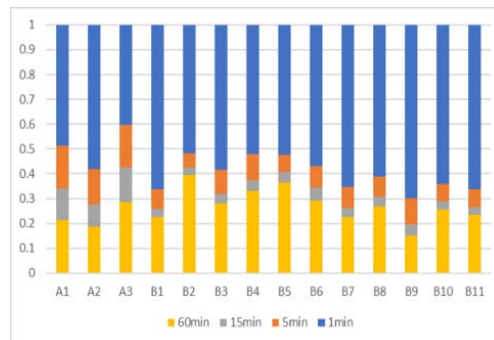
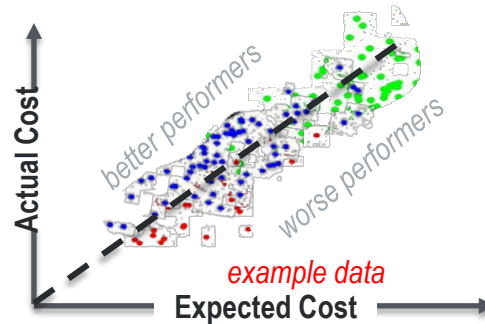
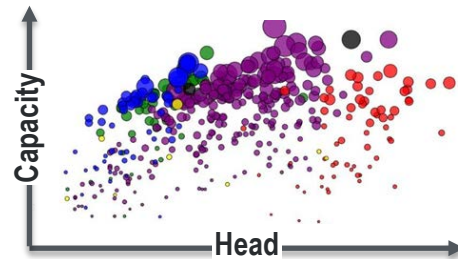
Are the hydroAMP data comprehensive? How are condition data distributed among components?

Data analytics for the Electric Utility Cost Group Hydroelectric Productivity Committee

Peer groups for cost benchmarking are established by multiple factors, including turbine type.

Individual facility cost-performance is assessed against a reference cost function in each peer group..

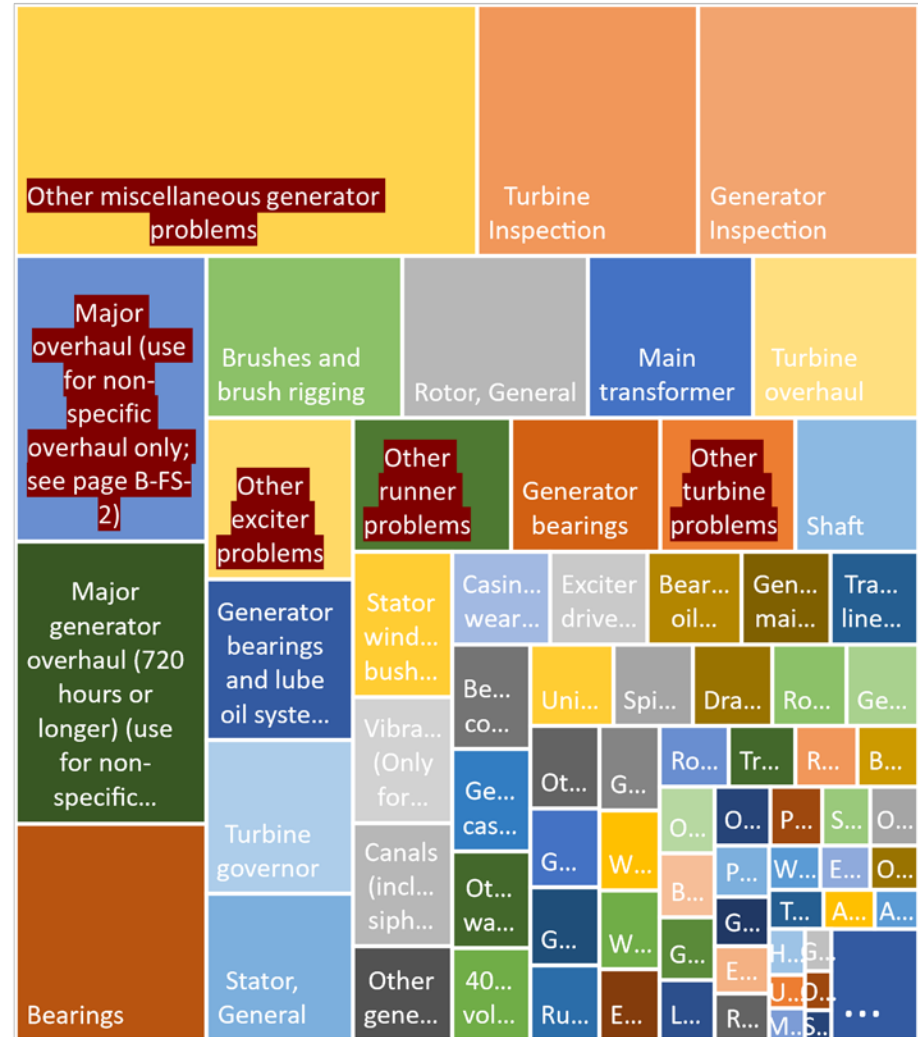
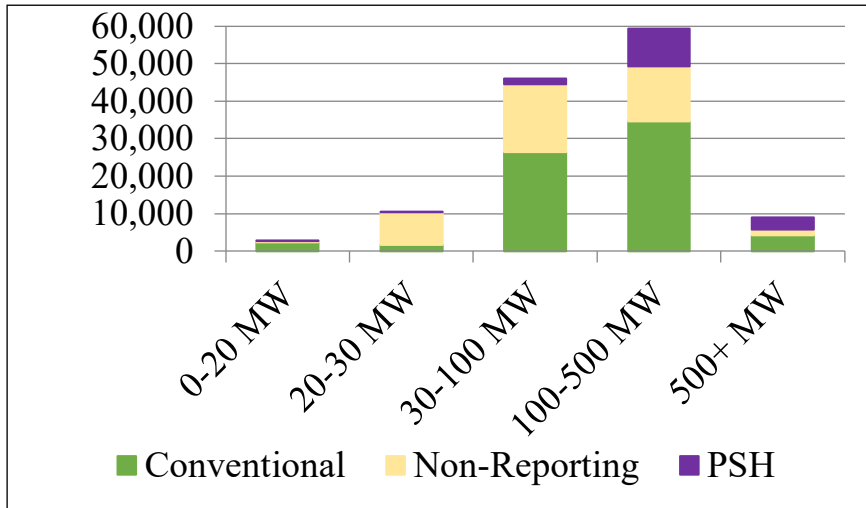
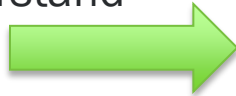
Analyses of EUCG member-facility time series data show that fidelity in metrics of operational variability require high-frequency (e.g. 1-minute) data.



- The EUCG business model requires members to contribute qualified data as a pre-requisite to accessing benchmarking results, ensuring that all are invested and contributing fairly to robust data and statistics.
- ORNL HFI applies its data analytics capability to the EUCG data under a non-disclosure agreement with EUCG. In return, ORNL gains insight into benchmarking cost trends and best practices.
- ORNL HFI also uses high-quality EUCG data to pilot new analyses and indicators of costs and other factors in asset management decision-making.

HFI analysis of Generation Availability Data System (GADS) data

- Vagueness in unit outage cause coding limits ability to understand outage trends
- Non-reporting of configuration data limits data usefulness



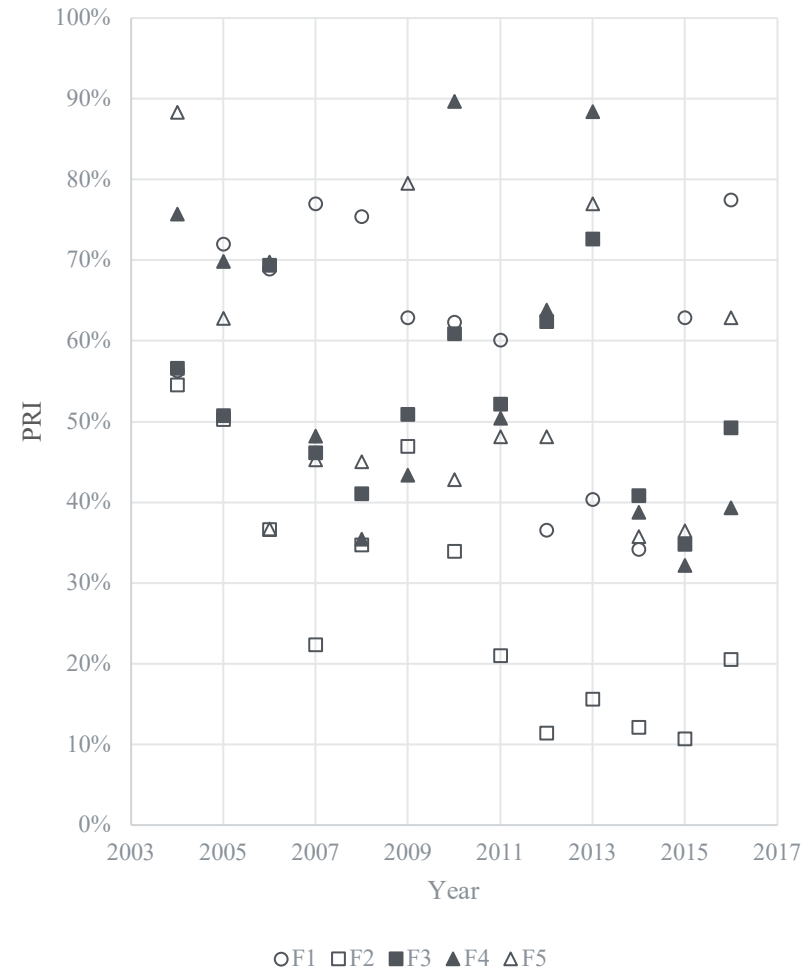
- **Powertrain Reliability Index:**

- Dispatch models currently meet environmental requirements and then dispatch for efficiency or value.
- What if units were dispatched for reliability?
- How well does historical dispatch compare to the reliability-optimized dispatch?
- What reasons are there for dispatching unreliable units first?
 - F2 dispatched their least reliable unit more than the other three units for six straight years

- **Conference Papers:**

- IEEE Probabilistic Methods Applied to Power Systems (FY18 Q3)
- ViennaHydro (FY19 Q1)

Annual Powertrain Reliability Index for Five Four-Unit North American Facilities



- **O&M Effects of Intensifying Dispatch Variability**
 - *PG&E partnership identified and NDA signed*
 - *Summary and Specification document*
 - *Data Acquisition*
 - *Data Characteristics and Sufficiency Report*
- ***Journal Manuscript Submissions:***
 - *The Effect of Parameter Uncertainty on Hydropower Asset Replacement Cost Models: ASCE Journal of Uncertainty and Risk Analysis*
 - *Whole Life Cost Model role in Capital Investment Strategies: ASCE Journal of Uncertainty and Risk Analysis*

- **O&M Effects of Intensifying Dispatch Variability at PG&E Helms**
 - *Draft confidential report Q1 FY20*
 - *Final confidential report Q2 FY20*
 - *Final public report Q2 FY20*

- **Fleet-wide Cost-Condition-Availability Assessment**
 - *Specification and Summary Guides Q4 FY20*
 - *Database build Q4 FY20*