High Performance Agent-based Simulation with GridLAB-D

HiPAS GridLAB-D

CEC Project EPC-17-046

SLAC National Accelerator Laboratory
PI: David P. Chassin, PhD

Operated by Stanford University for the US Department of Energy under contract DE-AC02-76SF00515.

LF ENERGY ARRAS

U.S. DEPARTMENT OF ENERGY | Stanford University

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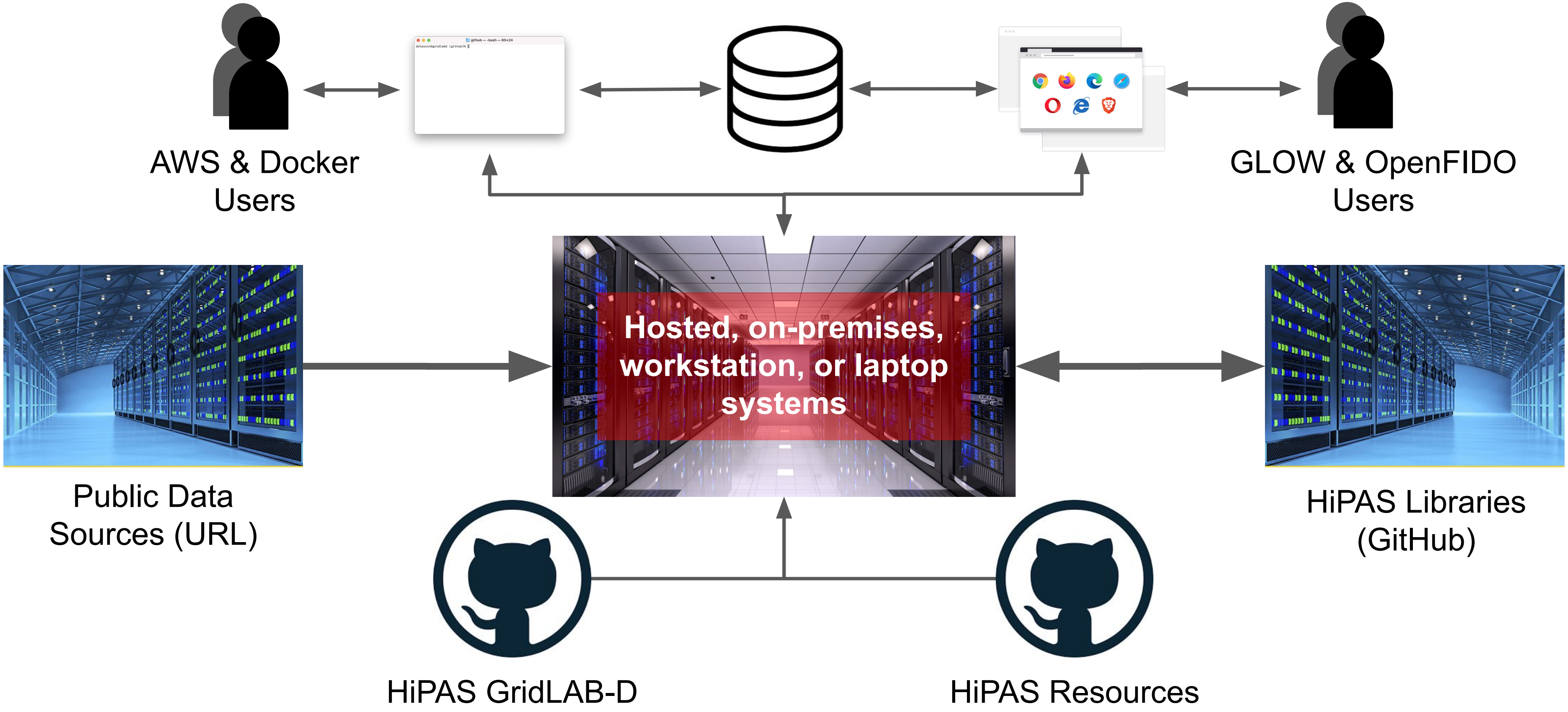
Meeting agenda

- Project description
- Goals and objectives
- Summary of major technical tasks
- Summary of results
- Conclusions and moving forward
- Q&A / Discussion

Project Description



Project goals and objectives

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The Problem

- GridLAB-D vital in power system simulation
- Renewables, storage, demand response
- DOE version limitations hamper usability

Target Audience

- Utility planners
- Engineering consultants and researchers
- Hardware and software vendors
- Energy/climate regulators & policy-makers

Product Delivery

- Commercial partner for long-term support

Goals

- More widely usable/functional version
- Broad set of performance enhancements
- Foundation for long term support

Objectives

- Identify and address key use-cases
- Evaluate performance improvements
- Open-source delivery and support
- Collaborations with CEC/DOE projects
  - OpenFIDO (CEC-17-047)
  - Hitachi GLOW (CEC-17-043)
  - GRIP (DOE GMLC climate resilience)

Summary of major project tasks

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Task 2 - Requirements Analysis

- HiPAS GridLAB-D Release Requirements Presentation

Task 2.1 - Use Case Requirements
Task 2.2 - Performance Baseline
Task 2.3 - Software Upgrade Design
Task 2.4 - Performance Specifications
Task 2.5 - Testing Plan
Task 2.6 - Software Design

Task 3 - Software Implementation

- Release Candidate 1
- Software Design Implementation CPR
- Software Implementation Presentation

Task 3.1 - Multi-threading Iterators
Task 3.2 - Job Control
Task 3.3 - Multi-threaded Solvers
Task 3.4 - Stochastic Properties
Task 3.5 - Fast Data Access
Task 3.6 - Fast Powerflow Solver
Task 3.7 - Online Documentation
Task 3.8 - Candidate Release 1

Summary of major project tasks (continued)

Task 4 - Performance Analysis

- Release Candidate 2
- Performance Evaluation Presentation
- Performance Analysis CPR Report

Task 4.1 - Performance Evaluation 1

Task 4.2 - Issues Tracking and Resolution

Task 4.3 - Analysis

Task 4.4 - Performance Evaluation 2

Task 4.5 - Release Candidate 2

Task 5 - Integrated Production Release

- Final Production Release Presentation

Task 5.1 - Support Release Production

Task 5.2 - Final Product Documentation

Task 5.3 - Final Release Product

Task 6 - Evaluation of Project Benefits

Task 7 - Technology Transfer

HiPAS Technical Approach: System Components

HiPAS Resources on GitHub (Arras Energy)

GridLAB-D: enhanced version of GridLAB-D

Templates: standard analysis methods

Weather: historical, current, and forecast data

Libraries: standard object data

Models: standard models for validation

Benchmarks: performance benchmark models

Examples: sample models used in tutorials

- All application resources are open source

GridLAB-D Components

Converters: automatic input/output converters

Geodata: GIS data handling

Python: Python code integration

Subcommands: embedded analysis resources

Tools: general purpose utility tools

- All public component code is open source
- Supports integration of private components

HiPAS Technical Approach: CI/CD

Continuous Integration

- Deliver apps from multiple developers/teams
- Introduces automation in development stages
- Solution to problem of integrating new code

Continuous Delivery

- Implements a pipeline of delivery/update tasks
- HiPAS uses GitHub "DevOps" methodology

Repository	Status
GridLAB-D	master passing · develop passing
Templates	master passing · develop passing
Weather	validate passing
Library	validate passing
Models	validate passing
Benchmarks	Manual test (see README.md)
Examples	Manual test (see README.md)

Example CI/CD status report from HiPAS GridLAB-D on GitHub shows development and deployment status.

HiPAS Use-Cases

Use-Cases Identified by TAC

1. Hosting Capacity (ICA)
2. Tariff Design
3. Electrification
4. Resilience (GRIP)

Notes: these are delivered using templates

Other Use-cases

1. CYME Converters (Version 5, 8, 9)
2. NERC Load Composition Analysis
3. Weather history, typical, current, forecast
4. Geographic datasets
   a. Vegetation
   b. Census regions & address resolution
   c. Distance calculations
   d. Fire hazards
   e. Powerline sag, clearance, and contact
   f. Utility/service providers
   g. Weather (local, regional)

Overview of HiPAS Capabilities

Deployment & validation of new capabilities

1. Weather data (forecasts)
2. Geographic data and models (vegetation)
3. Advanced load models (AMI data)
4. Utility assets (poles)
5. Resilience analysis (pole failure, line contact)
6. Market data (CAISO, ISONE)

Validation results

1. NG 2000-feeder performance test
2. SCE resilience analysis

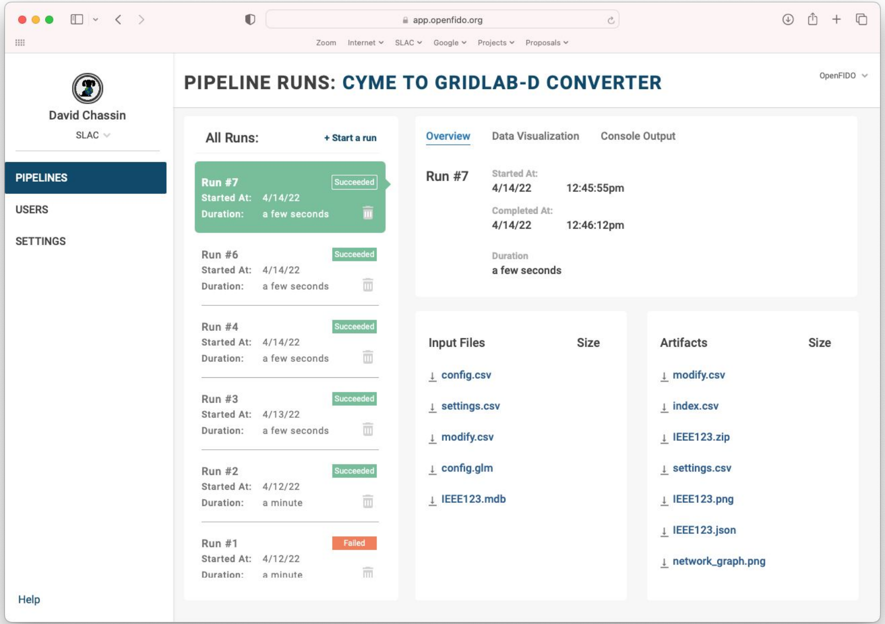
Use-Cases templates

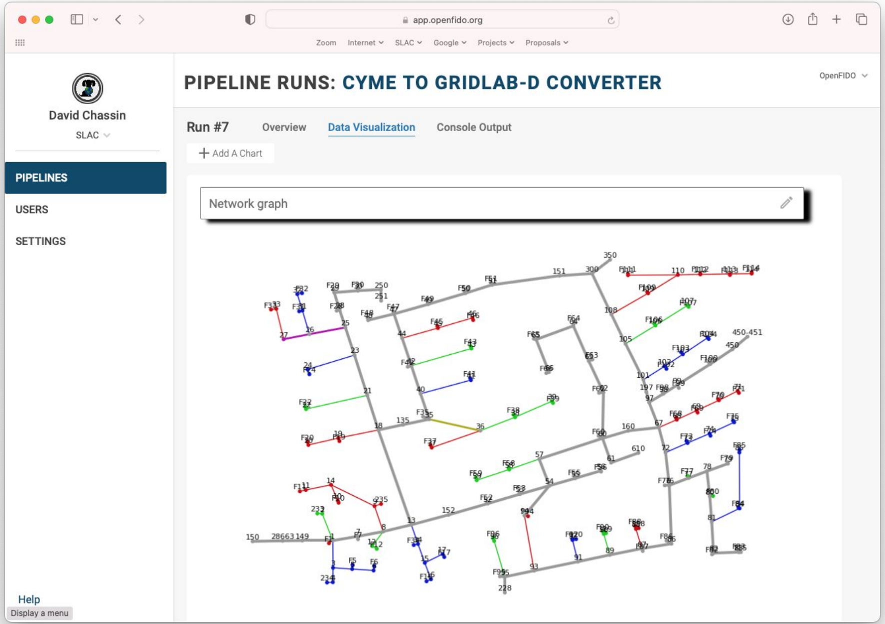
1. Hosting capacity analysis
2. Tariff design analysis
3. Electrification analysis
4. Resilience analysis

Technology transfer

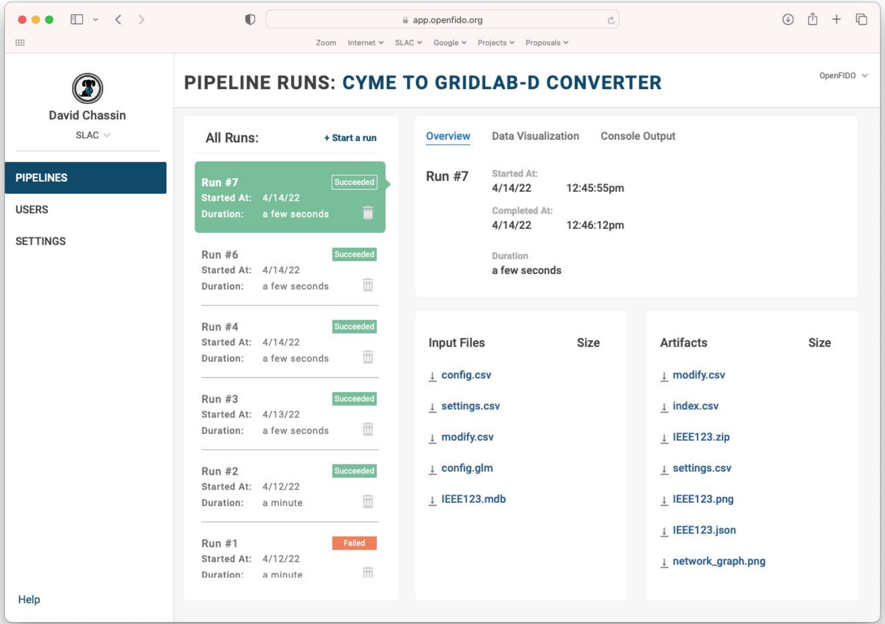
1. Linux Foundation Energy (Arras Energy)
2. AWS and Dockerhub support
3. Training and tutorial videos
4. IEEE Credentialed Instruction (CEU, PDH)

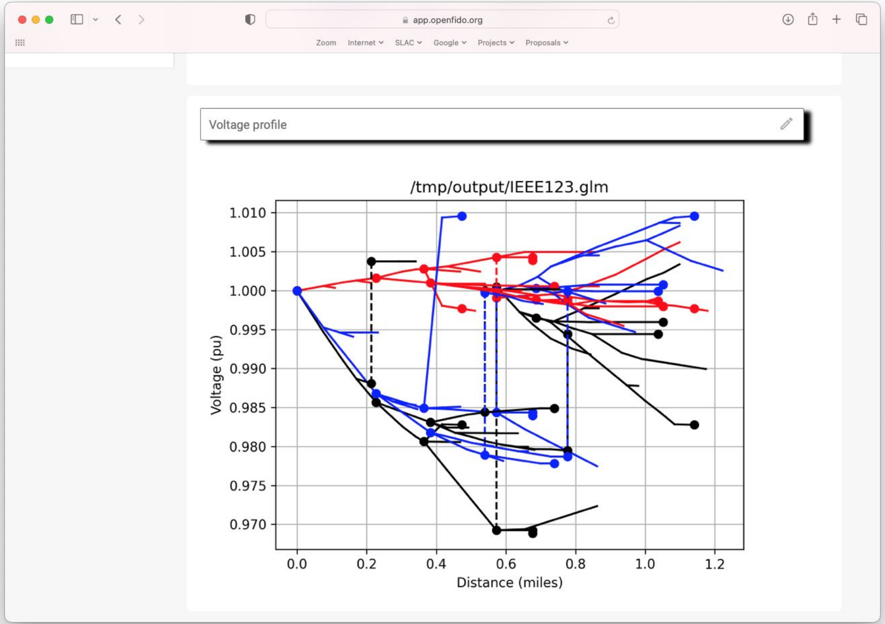
HiPAS Use-Case: Cyme Model Conversion





HiPAS Use-Case: Cyme Model Conversion





NG Long Term Load Forecast Methodology

Objectives:

- 15-year load forecast for NY
- Include renewables and DERs

Approach:

- Convert CYME to GLM
- Link GLM to annual loadshapes
- Simulation 8760 for year 1
- Extract feeder demand
- Extrapolate year 2 to 15

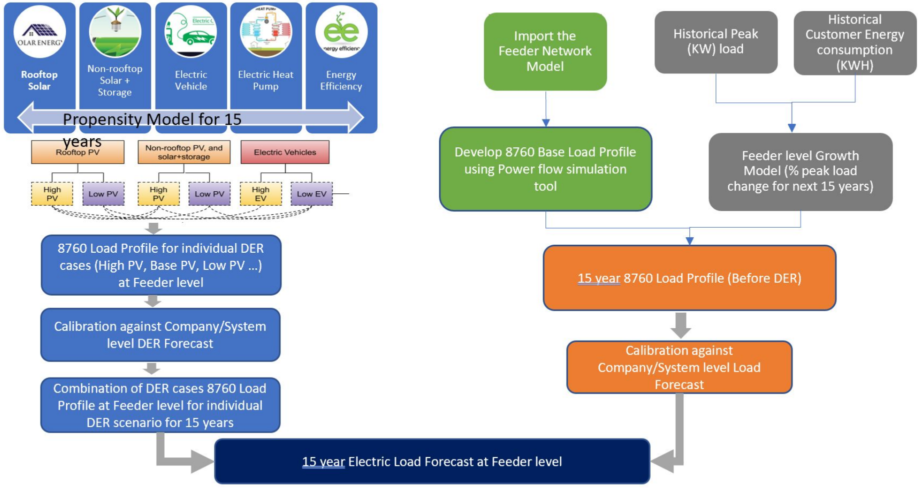


Image courtesy Hitachi America

NG 2000 Feeder Performance Evaluation

Test on ~2000 feeders from National Grid

- Feeders processed with CYME converter (>98% ok)
  - Solutions verified against 2021 load forecast solutions
  - Remaining errors due to model/data issues in CYME
- Findings using HiPAS GridLAB-D vs. DOE GridLAB-D
  - Simulation speed up (>99% faster)
  - AWS (c5a.8xlarge 32 vCPU 64GB) cost reduction (>99% savings)
  - Validated also on c5a.24xlarge 96 vCPU 192GB

Results of testing and validation: Cyme Converter

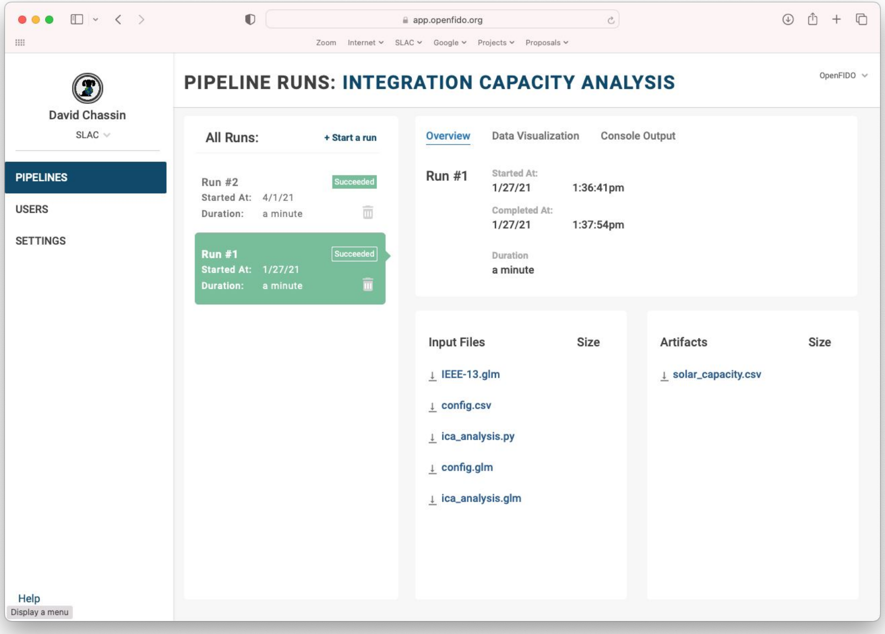
National Grid Load Forecast (LGF) Study

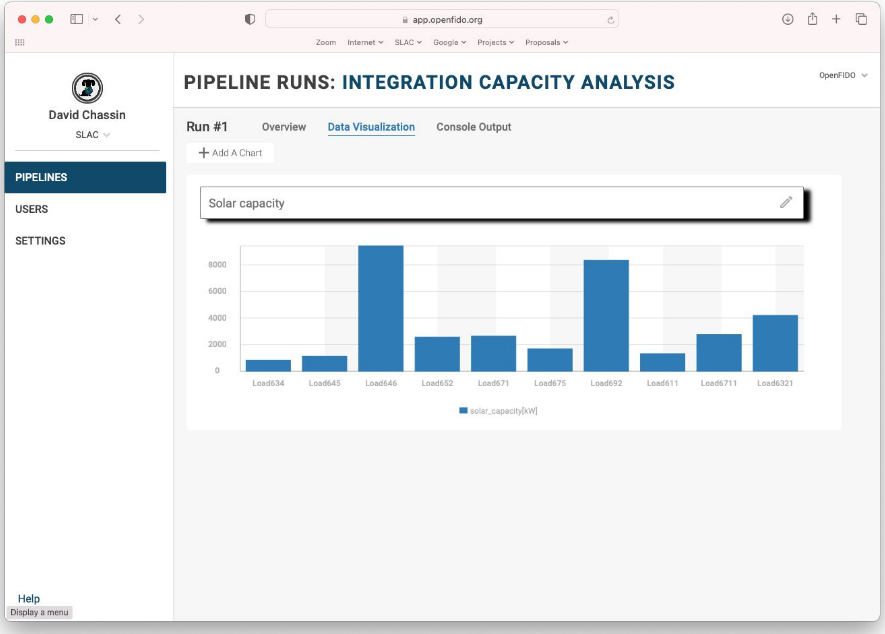
- 15 year load growth projection
- Analysis is updated annually
- 2021 LGF done w/DOE GridLAB-D
- 2022 LGF done w/HiPAS GridLAB-D
- Converted ~2000 Cyme feeders
- Used built-in Cyme converter
- Included weather and solar PV

Results of National Grid LGF Study

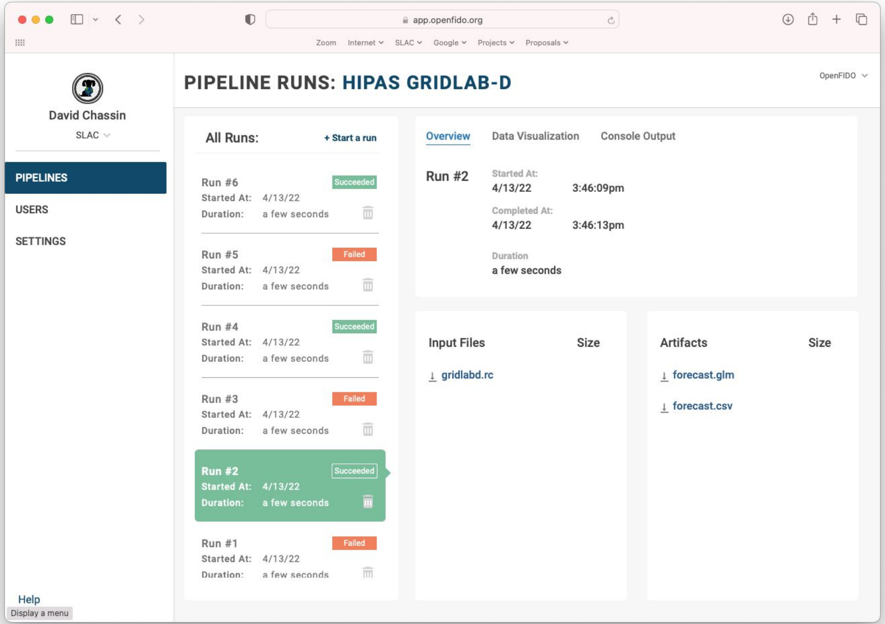
- Generated HiPAS GridLAB-D models
- 97.5% success CYME model input
- 2.5% required manual intervention
    - Cyme network model errors
    - Cyme load model errors
    - Cyme-GridLAB model mismatches
- Validated based on energy consumption relative to 2021 within load growth

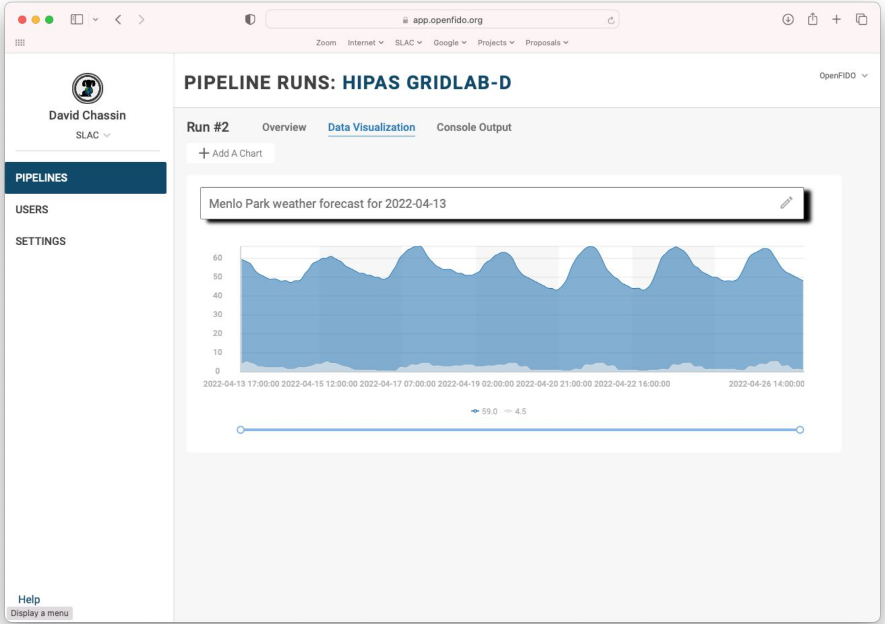
HiPAS Use-Case: Integration Capacity Analysis



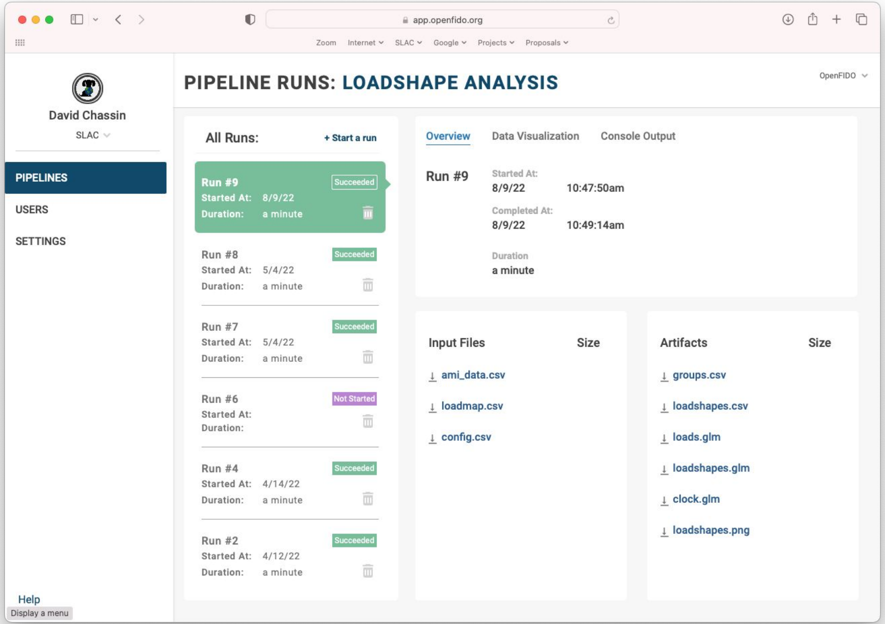


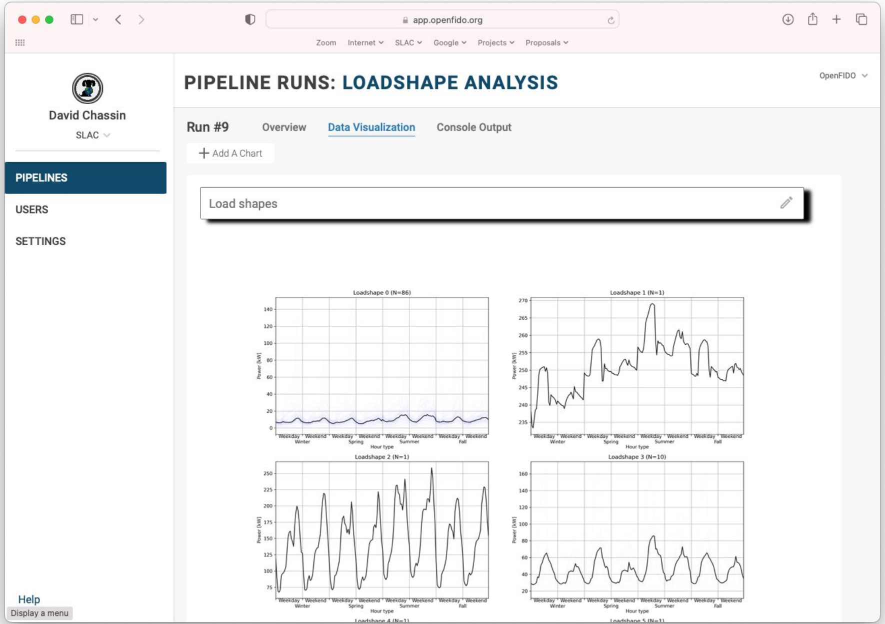
HiPAS Use-Case: Weather forecasting



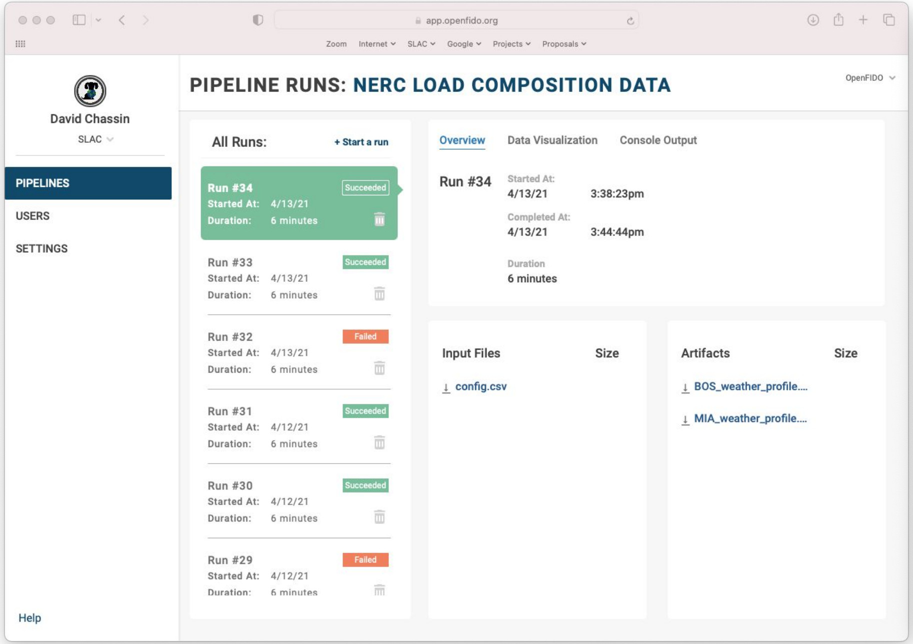


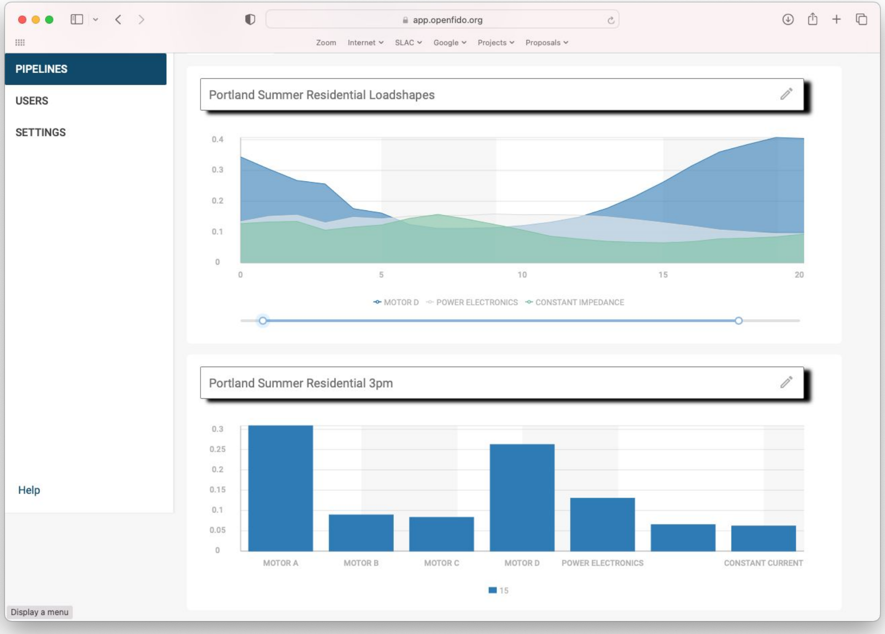
HiPAS Use-Case: Loadshape Analysis



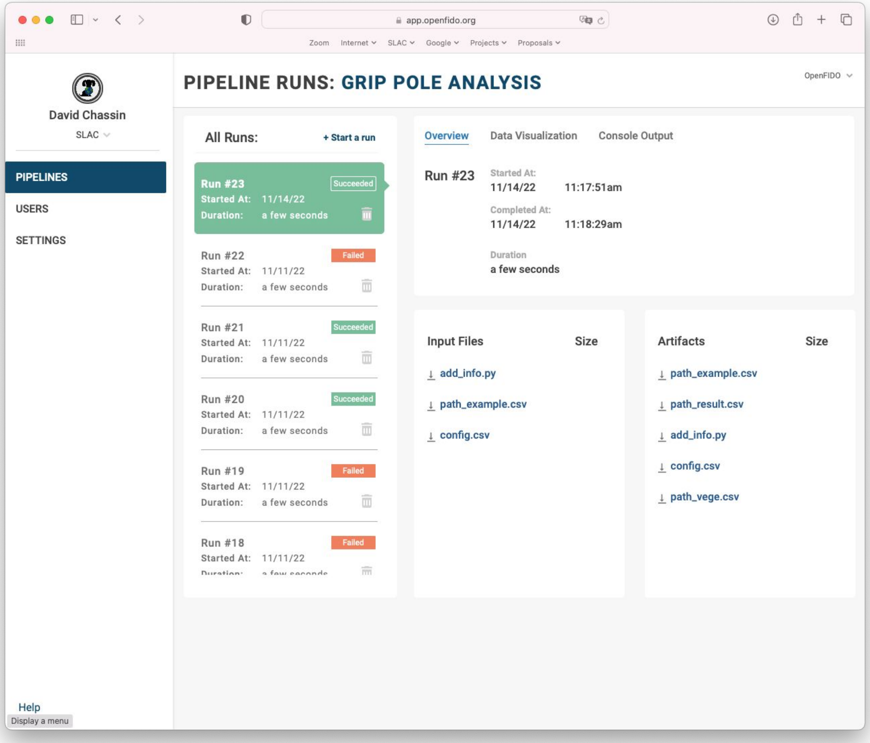


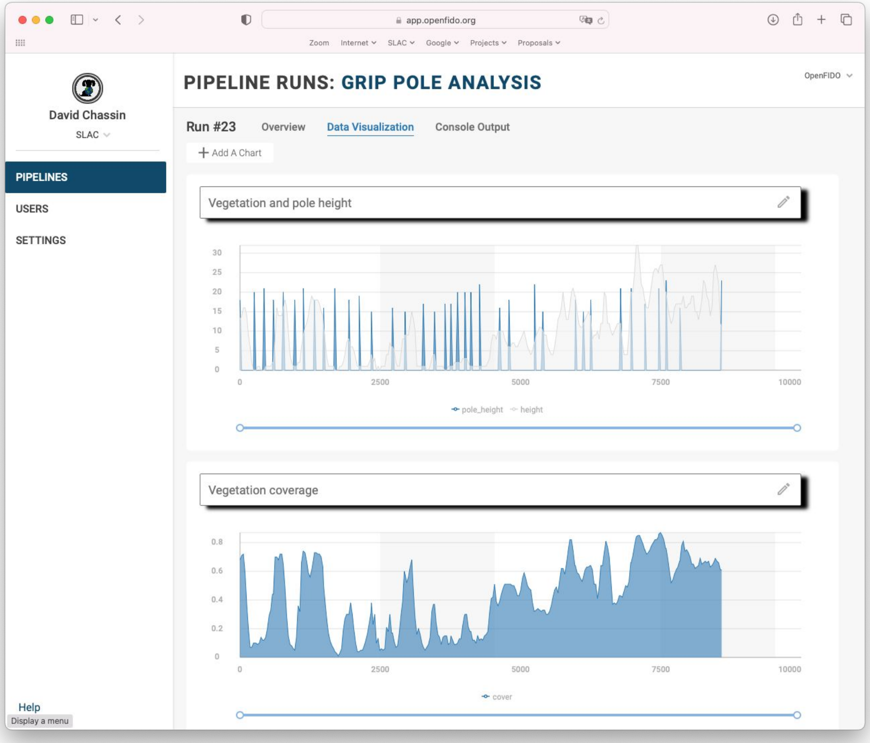
HiPAS Use-Case: Load Composition Analysis



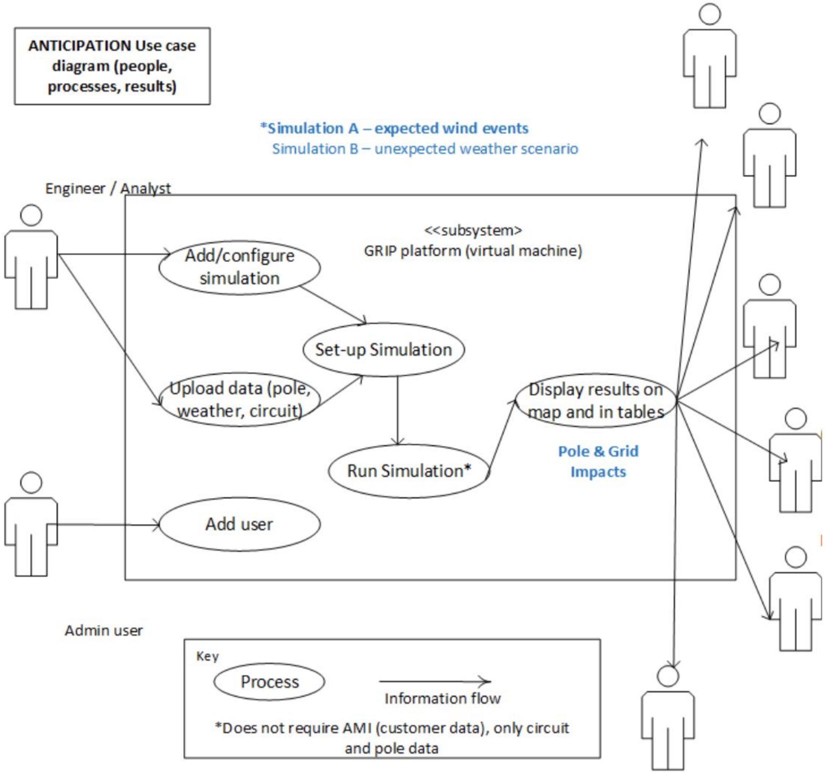


HiPAS Use-Case: Pole Vulnerability Analysis





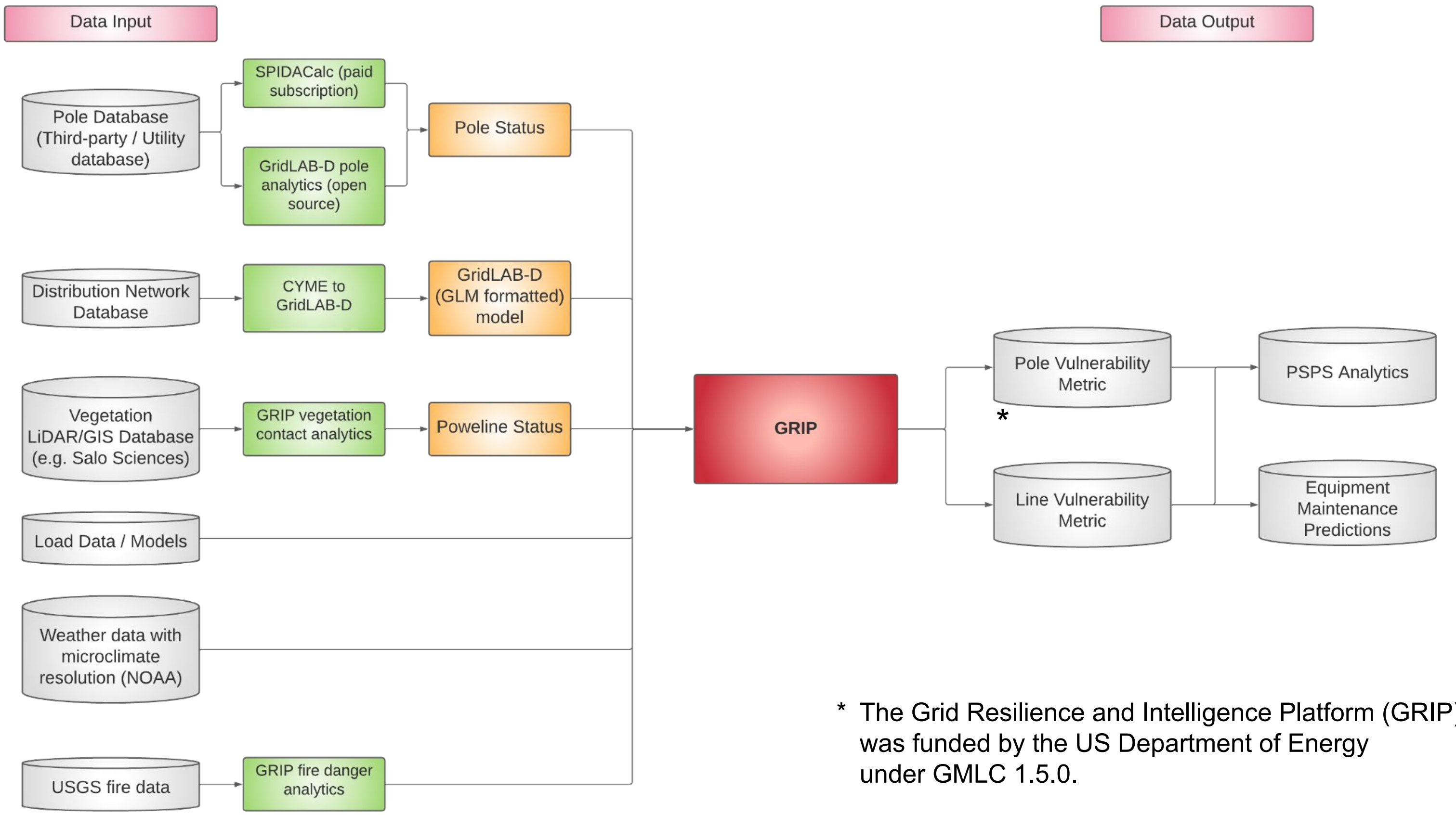
SCE Resilience Use-cases



Identified use-case scenarios:

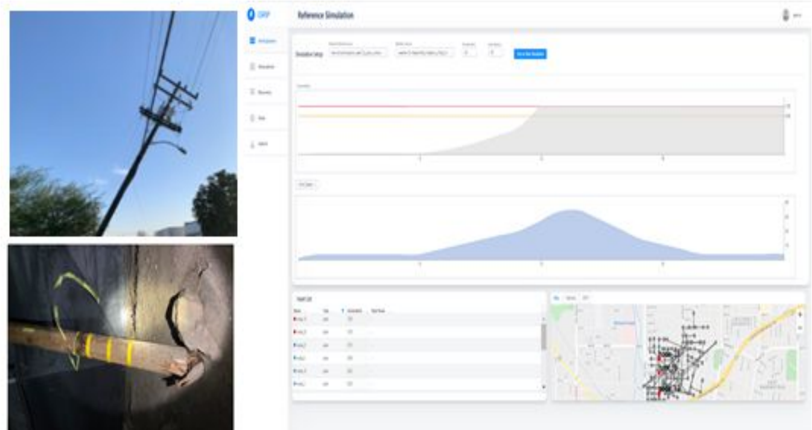
1. Which poles to replace?
2. Assess system stability
3. Identify fire-risk areas where poles may fall
4. Where to stage field crew
5. Where are poles likely to fail - day of events.
6. Maximizing stability during a wind storm

SCE Resilience Analysis Methodology



* The Grid Resilience and Intelligence Platform (GRIP) was funded by the US Department of Energy under GMLC 1.5.0.

SCE Resilience Analysis Evaluation

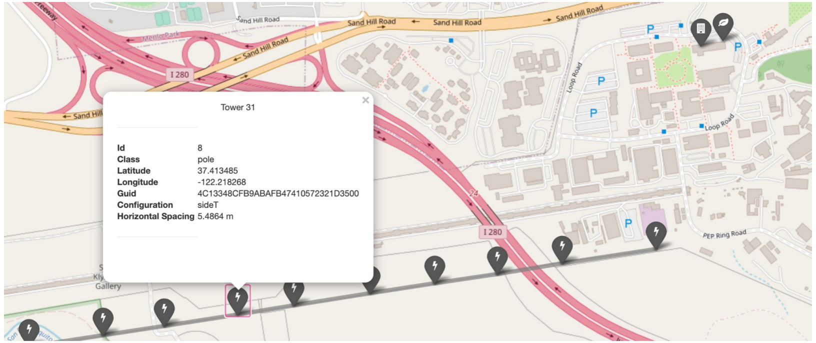


Pole vulnerability (IOU-driven use-case)

Test using failed pole data

Vegetation/ Fire-Risk - Model cables, vegetation (incl. Using lidar), etc.

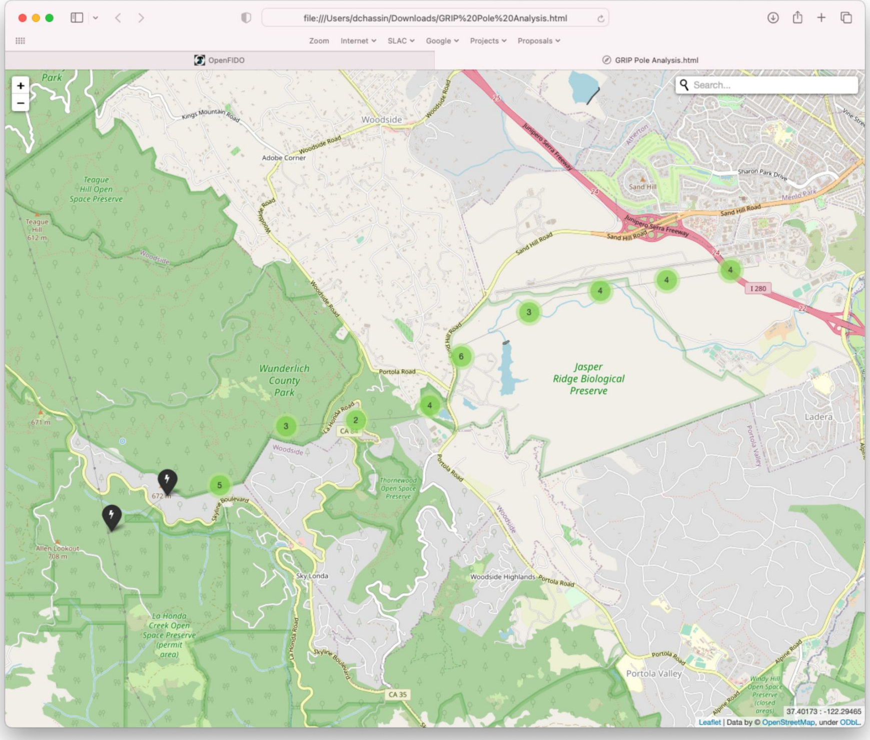
Final Test, Integrate and deploy

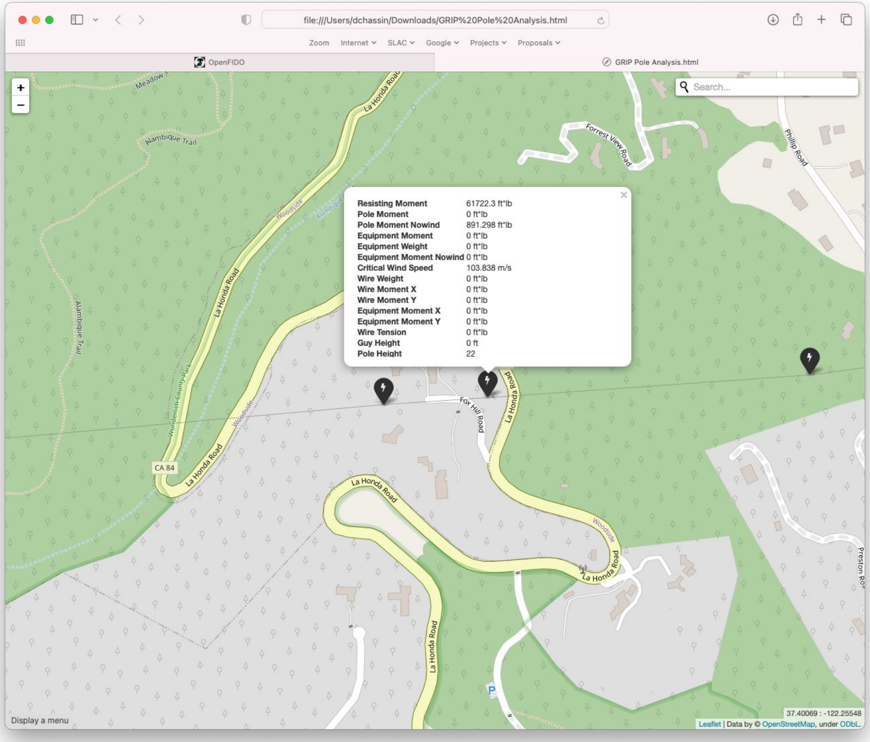


Three use-cases developed for SCE

1. Bulk pole analysis (integration with SPIDACalc for pole database and validation against standards)
2. Pole database integration with network models
3. Vegetation risk use-case

HiPAS Use-Case: Pole Vulnerability Analysis





Resilience analytics metrics and results

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Included in GridLAB-D powerflow module

- Pole object
- Pole configuration
- Pole mount
- Linked to overhead line object

Uses pole databases with lat/long information

- Moments used to evaluate resilience metrics
- Pole stresses validated with SpidaCALC

```
object pole
{
    pole_status "OK";
    tilt_angle "0 deg";
    tilt_direction 0 deg";
    weather "<climate-object>";
    configuration "<pole-configuration-object>";
    install_year "1970";
    repair_time "24 h";
    wind_speed 0.0 m/s;
    wind_direction 0.0 deg;
    wind_gusts 0.0 m/s;
    pole_stress "0 pu";
    pole_stress_polynomial_a "0 ft*lb";
    pole_stress_polynomial_b "0 ft*lb";
    pole_stress_polynomial_c "0 ft*lb";
    susceptibility "0 pu*s/m";
    total_moment "0 ft*lb";
    resisting_moment "0 ft*lb";
    pole_moment "0 ft*lb";
    pole_moment_nowind "0 ft*lb";
    equipment_moment "0 ft*lb";
    equipment_moment_nowind "0 ft*
    critical_wind_speed "0 m/s";
    guy_height "0 ft";
}
```

```
object pole_configuration {
  pole type "WOOD";
  design_ice_thickness 0.25;
  desing_wind_loading 4.0;
  design_temperature 15.0;
  overload_factor_vertical 1.9;
  overload_factor_transverse_general 1.75;
  overload_factor_transverse_crossing 2.2;
  overload_factor_transverse_wire 1.65;
  overload_factor_longitudinal_general 1.0;
  overload_factor_longitudinal_deadend 1.3;
  strength_factor_250b_wood 0.85;
  strength_factor_250b_support 1.0;
  pole_length 45.0;
  pole_depth 4.5;
  ground_diameter 32.5/3.14;
  top_diameter 19/3.14;
  fiber_strength 8000;
  treatment_method "CRESOTE";
}
```

```
object pole_mount
{
    equipment link_id;
    height 0.0 ft;
    offset 0.0 ft;
    direction 0.0 deg;
    weight 0.0 lbs;
    area 0.0 ft;
}
```

Results of testing and validation: Resilience

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Docker in-house testing

Pole Analysis Validation w/Spidacalc

- Single pole analysis 4.3 sec
- Five poles 7.4 sec

Southern California Edison

Evaluation still underway

- Bulk pole analysis
- Pole analysis with network
- Vegetation contact w/incident training
- PSPS analysis pending

Upcoming evaluations

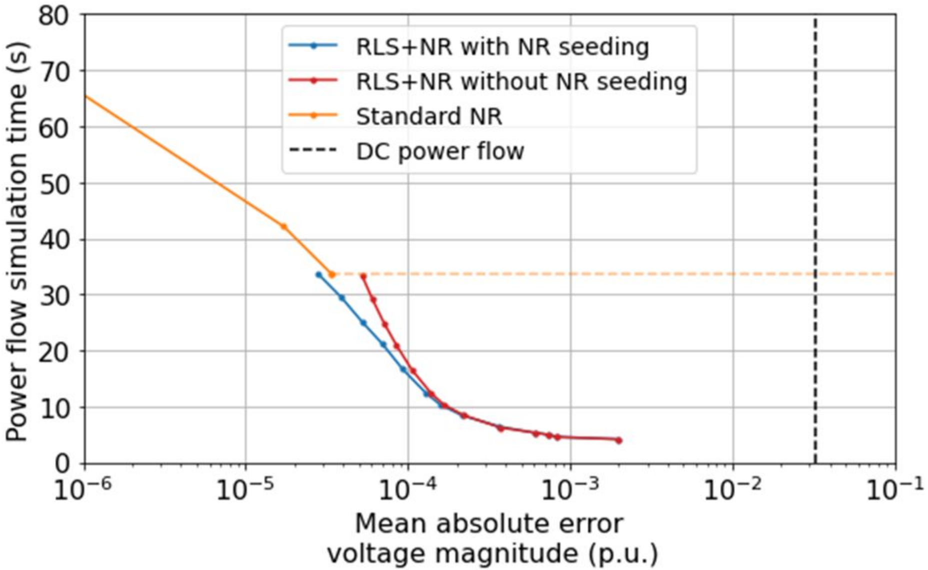
EPB (Chattanooga, Tennessee)

- Deploying GRIP on HiPAS (w/OpenFIDO)
- Pole analysis
- Vegetation contact
- Additional analytics for climate change resilience upon development.

Results of ML Powerflow Performance Evaluation

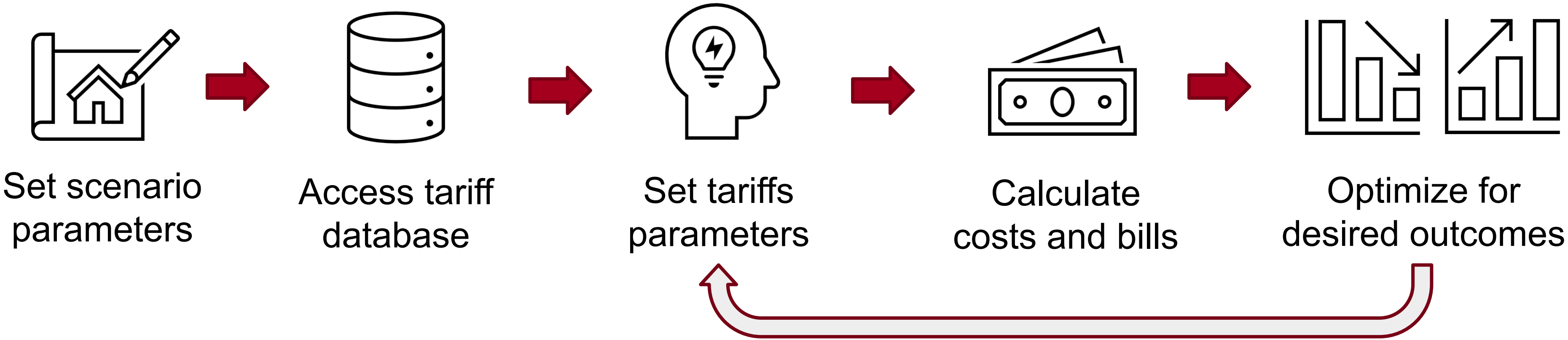
Journal article on hold:

- Recursive least squares method
- ML powerflow partly coded in Python
- Not production-ready
    - Need to be converted to C++
    - Topology changes
    - Capacitors controls
    - Regulators controls
- Follow-up under LF Energy TSC oversight



Tariff analysis use-case

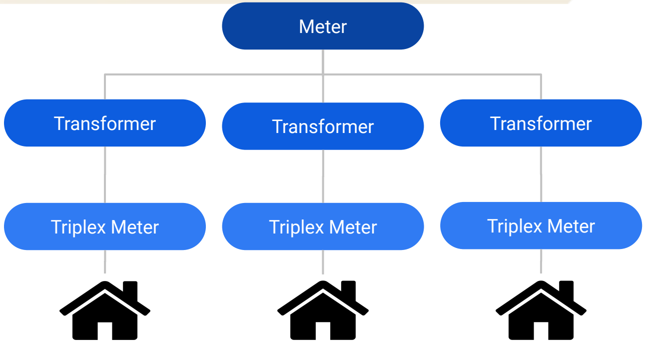
- Electric energy tariff analysis template available for HiPAS GridLAB-D
- Focus on residential tariffs for California IOUs
- Leveraging an open-source world-wide tariff database, OpenEi (NREL)

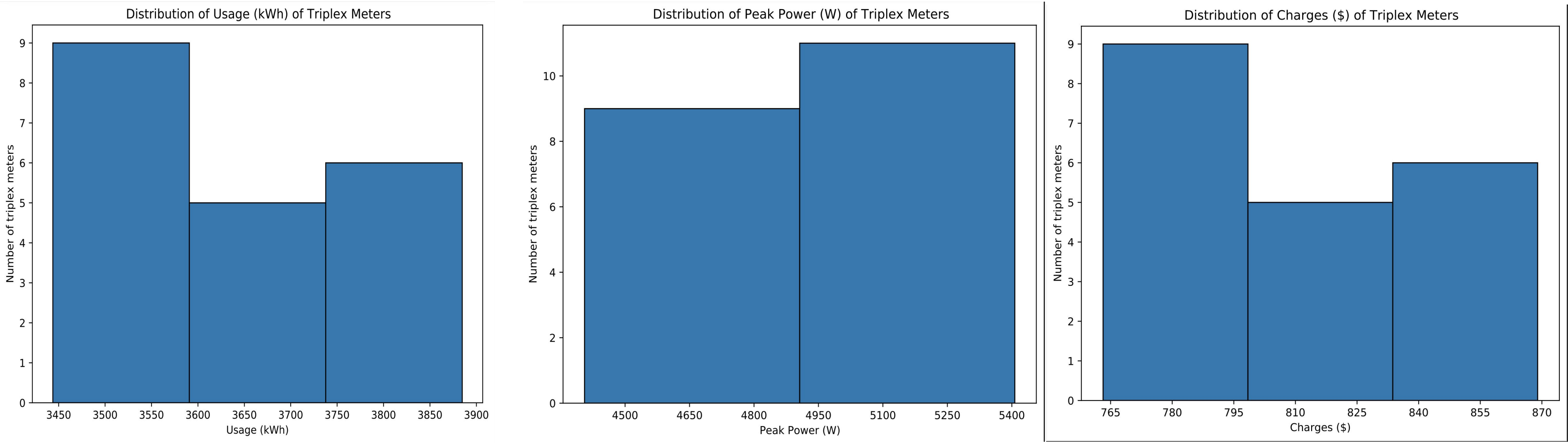


Tariff Design - Example study

Simulation Parameters:

- Jan 1, 2020 – Dec 31, 2020
- 27 houses in San Francisco
- PG&E E-TOU-C3 Region R





Result of testing and validation

Tariff Design

Solution speed

- 100 homes
- 1 year billing simulation at 1hr timestep
- 10 min (vs. 45 sec for non-billing run)

Accuracy

- 1 house
- 1 month billing simulation
- No measurable error

Electrification

Solution speed

- 90 homes
- 1 year billing simulation at 1hr timestep
- 10.3s

Accuracy

- 1 house
- 1 month electrification simulation
- N/A

Testing and validation: Lessons Learned

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Requirements

- Use-cases evolve quickly
- Data for use-cases is hard to find
- Vendors can be uncooperative/resistant
- Need standard approach to validation
- Need legal framework for data sharing

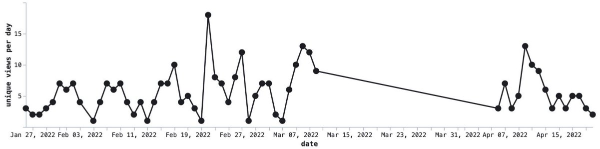
Implementation

- Dependencies across tools is challenging
- Python changes/updates frequent issue
- Utilities need more rapid tool deployment
- Utilities need time to validate tools
- Utilities rather host code than share data
- Security compliance not part of CI/CD

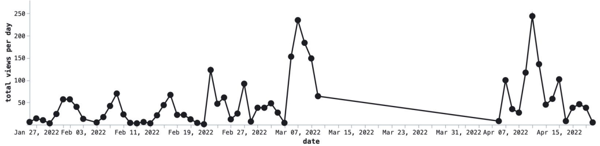
HiPAS GridLAB-D GitHub activity data collection

Views

Unique visitors

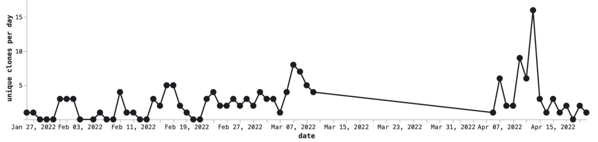


Total views

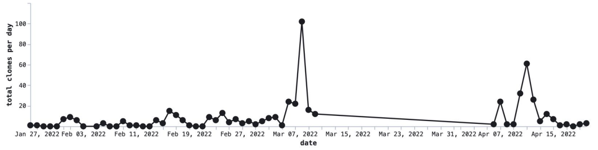


Clones

Unique cloners



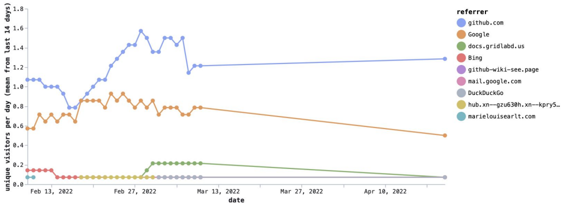
Total clones



Top referrers and paths

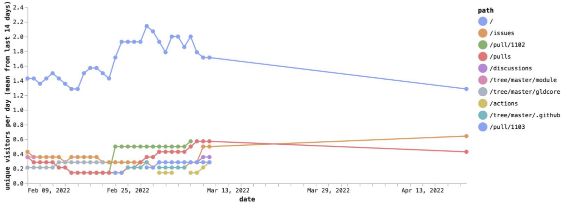
Note: Each data point in the plots shown below is influenced by the 14 days leading up to it. Each data point is the arithmetic mean of the "unique visitors per day" metric, built from a time window of 14 days width, and plotted at the right edge of that very time window. That is, these plots respond slowly to change (narrow peaks are smoothed out).

Top referrers



Top 15 referrers: 01: `github.com`, 02: `Google`, 03: `docs.gridlabd.us`, 04: `Bing`, 05: `github-wiki-see.page`, 06: `mail.google.com`, 07: `DuckDuckGo`, 08: `hub.xn--gzu630h.xn--kpry57d`, 09: `marielouisearlt.com`

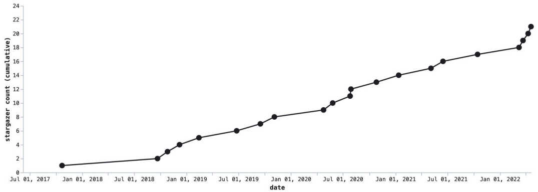
Top paths



Top 15 paths: 01: `/`, 02: `/issues`, 03: `/pull/1102`, 04: `/pulls`, 05: `/discussions`, 06: `/tree/master/module`, 07: `/tree/master/gldcore`, 08: `/actions`, 09: `/tree/master/.github`, 10: `/pull/1103`, 11: `/tree/develop`, 12: `/pull/1090`, 13: `/pull/1143`, 14: `/pull/1047`, 15: `/wiki/AWS-images`

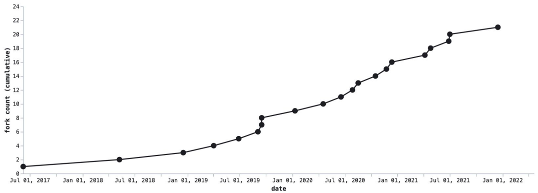
Stargazers

Each data point corresponds to at least one stargazer event. The time resolution is one day.



Forks

Each data point corresponds to at least one fork event. The time resolution is one day.



Other monitored resources:

- Dockerhub
- Amazon AWS

HiPAS GridLAB-D training (IEEE CEU/PDH)

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APPLIED ENERGY DIVISION

HiPAS GridLAB-D Training

SLAC National Accelerator Laboratory provides training to academic, industry, and vendors that wish to use the High-Performance Agent-based Simulation (HiPAS) version of GridLAB-D in their research, development, and operations. Staff in the Grid Integration Systems and Mobility group are experts on the design, development, and use of GridLAB-D, and related tools.

Training courses cover a range of topics from introductory material for newcomers to the world of agent-based power system simulation, intermediate topics on specific modules, including power systems, buildings loads, transportation infrastructure, and distributed energy resource integration, and advanced topics, include data handling, cloud computing, module development, and core development. Attendees will learn how to use GridLAB-D to simulate grid behaviour under deep electrification, DER integration, and tariff design. In addition, special topics may be addressed by request.

Instructors are highly experienced electrical and mechanical engineers who have worked with and developed tools using GridLAB-D for many years. Training courses are offered in 1/2-day or 1-day modules, depending on the topic and can be delivered on-line using Zoom, on-site at SLAC National Accelerator Laboratory, or off-site at a hosting facility. Off-site courses include GSA per-diem costs, unless instructors' travel, food, and lodging are prepaid.

About the Instructors *

David P. Chassin, PhD

David has more than 30 years experience in energy system modeling and simulation. He manages the Grid Integration Systems and Mobility at SLAC. He is the original developer of GridLAB-D and leads the development of the California Energy Commission EPIC projects to commercialize GridLAB-D for California's investor-owned utilities.

Alyona Teyber, MASc

Alyona has 7 years experience modeling and simulating power systems using GridLAB-D, as well as developing tools and applications based on GridLAB-D technology. Alyona leads research projects in grid resilience, distribution system electrification, and the integration of renewable resources in distribution system operations.

* Please note that instructors may change depending on the course date and location.

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APPLIED ENERGY DIVISION

GridLAB-D Training Course Application

Company name: ______________________ **DUNS:** ______________

Principal address: ______________________ **US Corporation?** [ ] Yes

______________________ (see Note 1) [ ] No

____

____

Contact name: ______________________

Contact email: ______________________

Contact phone: ______________________

Course dates: ____/____/20____ to ____/____/20____

Send an email request for training and support.

Please choose course topics:

	Topic	*Online Only*	*SLAC Hosts*	*Company Hosts*
[ ]	GridLAB-D Introduction (1/2 day)	$1250	$1750	$1250
[ ]	Distribution system modeling (1/2 day)	$500	$1000	$500
[ ]	Load modeling (1/2 day)	$500	$1000	$500
[ ]	Retail market/tariff design (1/2 day)	$500	$1000	$500
[ ]	Load electrification (1/2 day)	$500	$1000	$500
[ ]	Electric vehicle charger integration (1/2 day)	$500	$1000	$500
[ ]	Solar resource integration (1/2 day)	$500	$1000	$500
[ ]	High-performance simulation (1/2 day)	$500	$1000	$500
[ ]	Database operations (1/2 day)	$500	$1000	$500
[ ]	Cloud operations (1/2 day)	$1250	$1750	$1250
[ ]	Module development (1 day)	$2500	$3000	$2500
[ ]	Core development (1 day)	$2500	$3000	$2500
[ ]	Special topics (1/2 day)		(call for pricing)	
	Course administrative fee	$1000	$1000	$1000
	Subtotal:	$________	$________	$________
	Travel (see Note 2)	$0	$0	$________
	Total:	$________	$________	$________

Notes:

1. Foreign corporations require 60-90 days for US Department of Energy review and approval.
2. Please use GSA per diem rates for training location. Partners may provide travel, food, and lodging.

Please send your application to SLAC (pao@slac.stanford.edu)

Scan this QR code to get a copy of the training application form and access the online tutorial videos, or use the following link:

http://training.gridlabd.us/

Linux Foundation Energy (LF Energy)

HiPAS GridLAB-D Version 4.3.1 Released, Officially Becoming LF Energy Arras

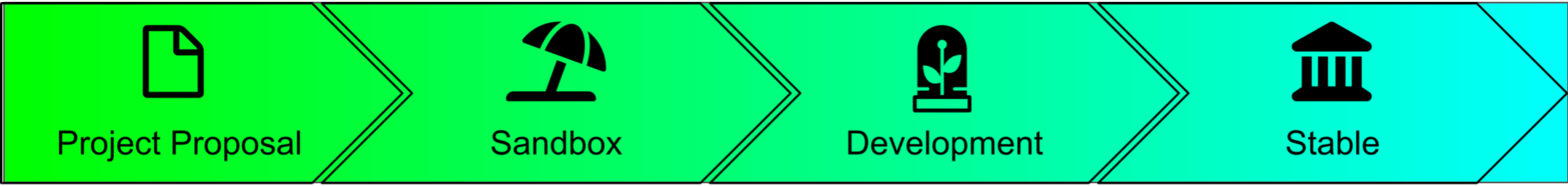
LF ENERGY ARRAS

BY DAN BROWN | JULY 13, 2023

Next Steps

Transfer to LF Energy is complete

- Project is in "sandbox" status until onboarding checklist is complete
- TSC managing transition to "development" status through 2023
- Anticipate "stable" status in 2024



Develop ideas, focuses	Form scope, gain consensus	Spec Building and User Feedback	Ready for production

Contribution Acknowledgments

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Anthony James (Resilience)
Frank Gonzales (Resilience)
Stacie Bartholow (Cyber-security)

National Grid

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Balaji Doraibabu (Load forecast study)
Sayonsom Chando (Load model validation)

Hitachi America Laboratories

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Joseph Chongfuongprinya (Cyme model)
Natsushiko Futamara (AWS performance)

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Johnson Hsiung (Electrification)

Jewel Newman (Tariff Design)

Michelle Huang (Electrification)

Jorge Higuera (Electrification)

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Sara Borchers (RA)

Adhithya Antonysamy (RA)

Questions, Answers, and Discussion

HiPAS GridLAB-D online	www.gridlabd.us or https://arras.energy/
SLAC Contact	David Chassin (dchassin@stanford.edu)
LF Energy Contact	John Mertic (jmertic@linuxfoundation.org)