CEC Advanced Simulation Program

Technical Advisory Committee

September 11, 2020

HITACHI
Inspire the Next

GRIDWORKS

SLAC NATIONAL ACCELERATOR LABORATORY

GRIDWORKS

Convene, educate, and empower stakeholders working to decarbonize electricity grids.

CEC Advanced Simulation Program TAC Meeting #5

GRIDWORKS

Today’s Objectives:

- Present project development updates
- Demonstrate new user interface
- Request TAC feedback on next steps
- Secure TAC participants in upcoming Testing Group

CEC Advanced Simulation Program

TAC Meeting #5 (September 2020)

EPC 17-043 GLOW

EPC 17-046 HiPAS

EPC 17-047 OpenFIDO

This presentation was prepared with funding from the California Energy Commission under grant EPC-17-046. SLAC National Accelerator Laboratory is operated for the US Department of Energy by Stanford University under Contract No. DE-AC02-76SF00515

U.S. DEPARTMENT OF ENERGY Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Agenda for Today

09:05	Introduction
09:15	OpenFIDO Update
09:25	HiPAS Update
09:45	Discussion & Feedback
10:10	Break
10:20	GLOW Presentation
10:40	GLOW Demonstration
11:30	Discussion & Feedback
11:45	Closing remarks

Three project discussed today

1. **OpenFIDO (CEC EPC-17-047)**

   A tool to support data exchange between tools in the program and tools used by California utilities

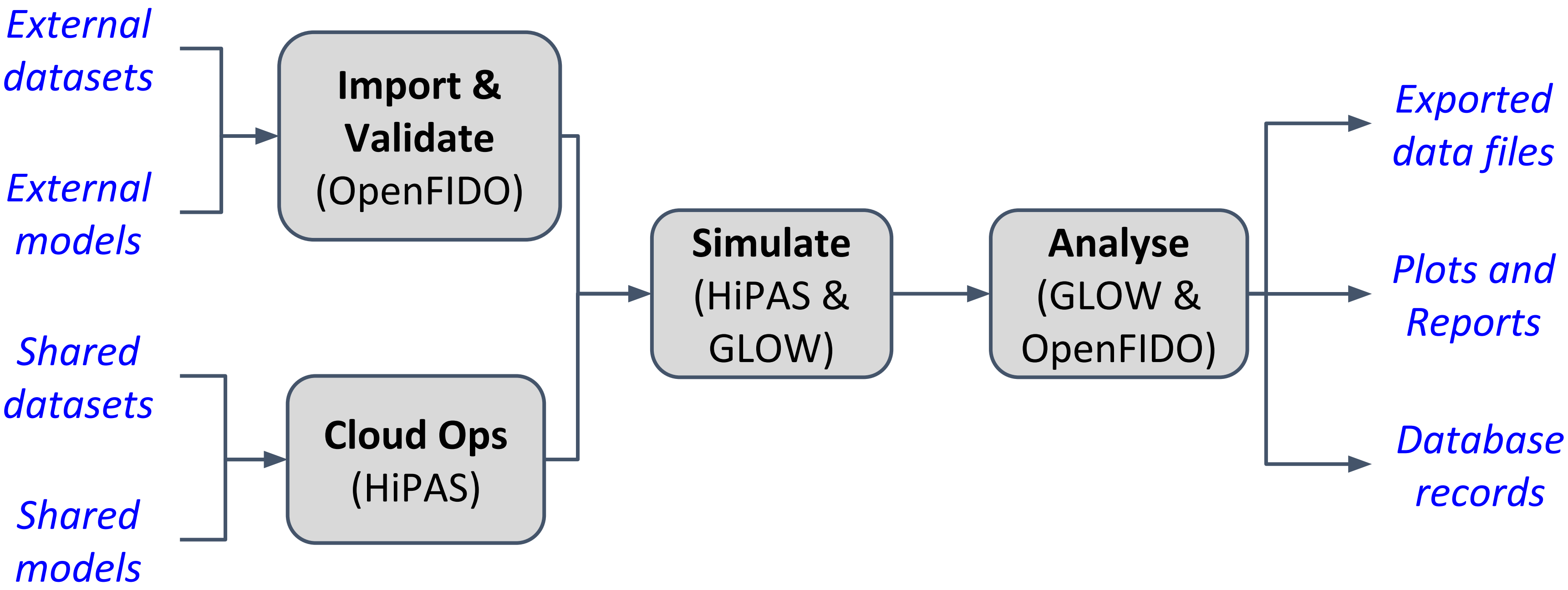
2. **HiPAS (CEC EPC-17-046)**

   A project to enhance GridLAB-D for major grid simulation use-cases identified by this committee

3. **GLOW (CEC EPC-17-043)**

   A user interface for GridLAB-D focusing on a key distribution system analysis use-case in California

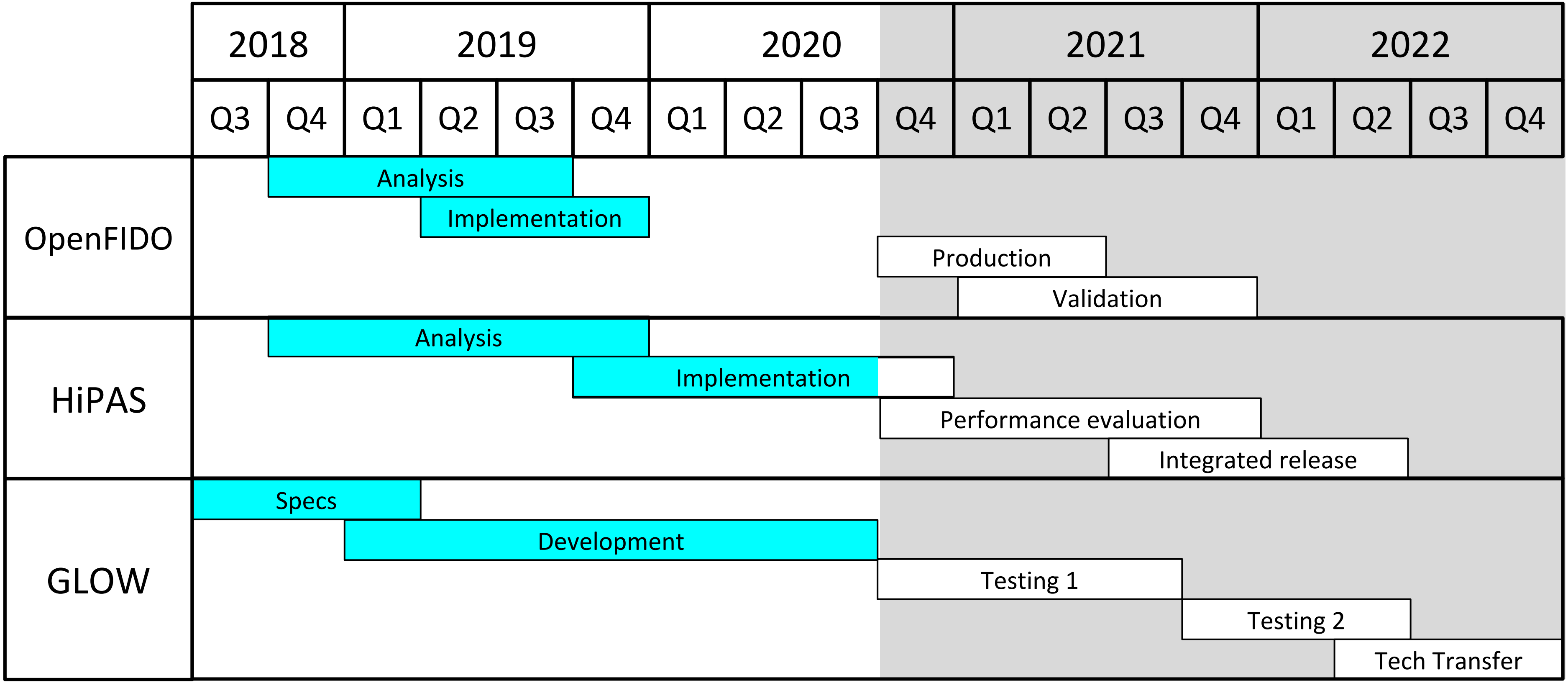
Program Overview



Project Team Roles and Responsibility

Activity	Design	Development	Validation	Commercialization
SLAC/Stanford	HiPAS	HiPAS	HiPAS	HiPAS
Hitachi	GLOW	GLOW	GLOW	GLOW
Gridworks	HiPAS			
National Grid			HiPAS	
PNNL		OpenFIDO		
Presence	OpenFIDO	OpenFIDO	OpenFIDO	OpenFIDO

Project timelines and status



OpenFIDO

TAC Meeting #5 (September 2020)

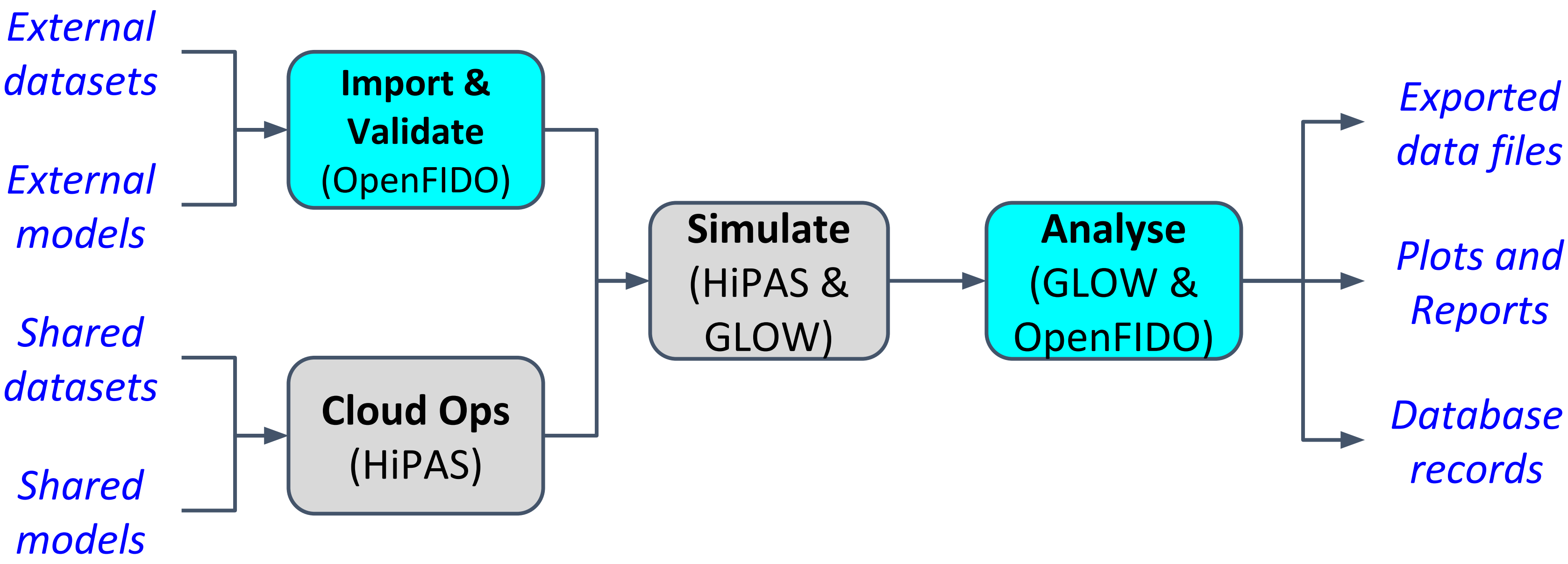
EPC 17-043	EPC 17-046	EPC 17-047
GLOW	HiPAS	OpenFIDO

This presentation was prepared with funding from the California Energy Commission under grant EPC-17-046. SLAC National Accelerator Laboratory is operated for the US Department of Energy by Stanford University under Contract No. DE-AC02-76SF00515

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Project Focus Area



Project Objectives

Provide framework for three utility data/model management use-cases

1. Data/model acquisition - collect from various tools and databases

   Include support for GridLAB-D, CYME, OMF, OpenDSS

1. Data/model curation - clean and collate, plot and report

   Include plot-viewer and HiPAS-developed post-processing tools

1. Data/model delivery - send back to various tools and databases

   All GridLAB-D export converters from HiPAS and NRECA are included

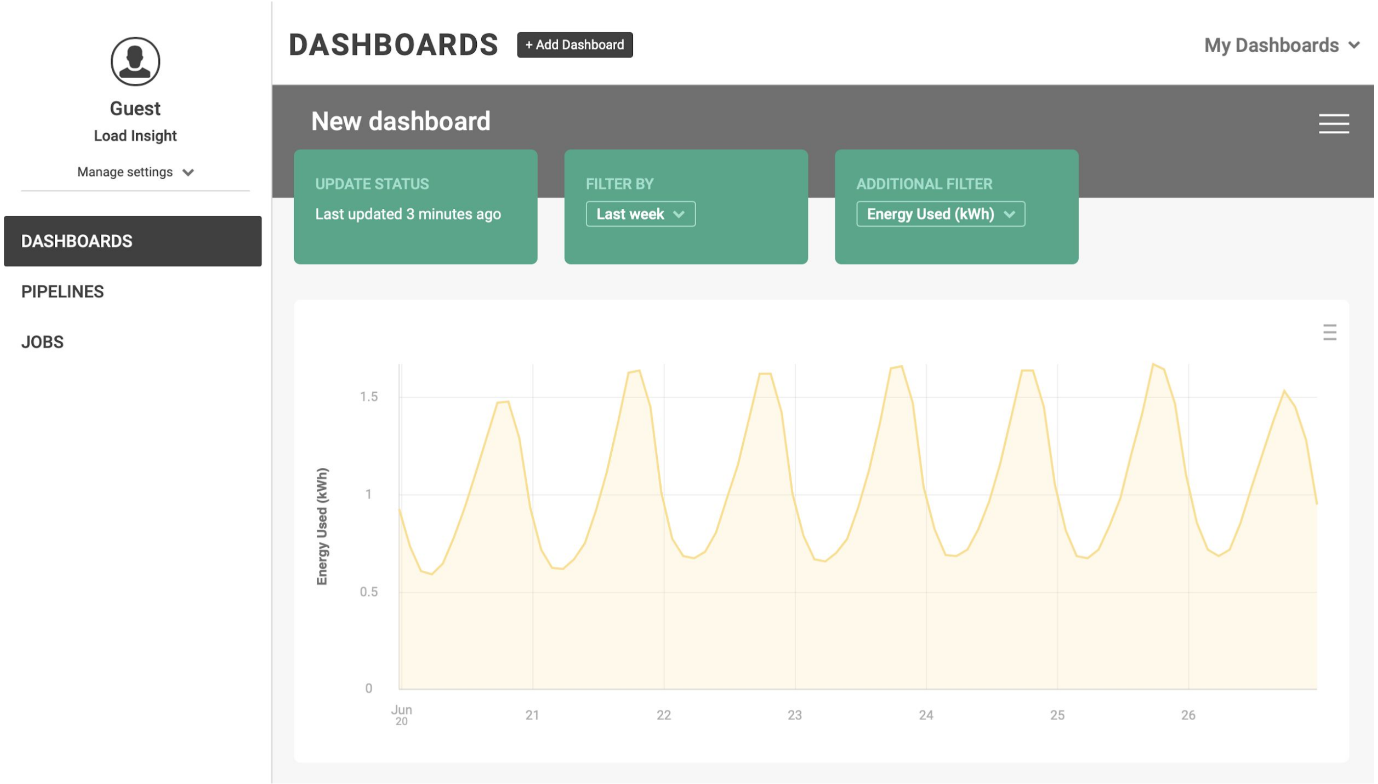
Project Status

SLAC

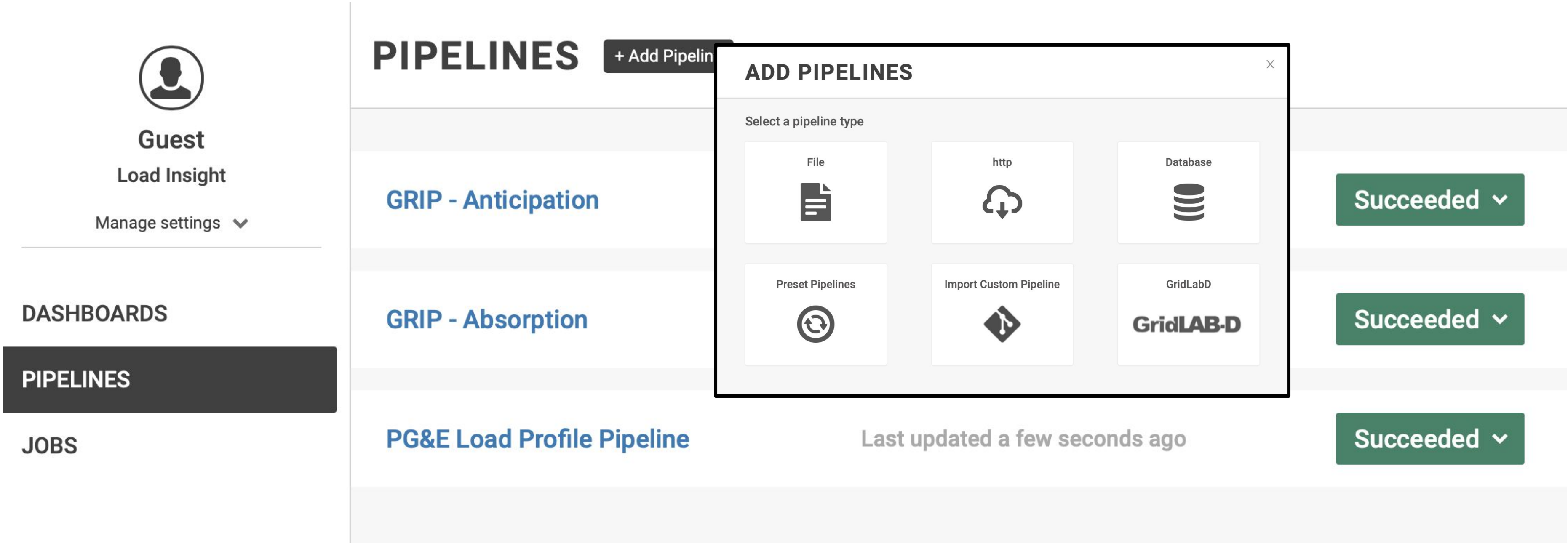
Overall Status

1. Data/model acquisition
   a. Existing tools are being transferred from GridLAB-D to OpenFIDO
   b. New tools are being developed by HiPAS team for active use-cases
2. Data/model curation
   a. Workflow manager prototype done, production version in progress
   b. Plot viewer prototype done, production version coming soon
3. Data/model delivery
   a. Tools transfer from HiPAS to OpenFIDO pending

OpenFIDO: Platform for LoadInsight-like tools



LoadInsight: focus on load data in utility analytics



Technology Foundation: LoadInsight (DOE TCF)

SLAC

Potential use-cases:

1. Engineering analysis
2. Load clustering
3. Load disaggregation
4. DER optimization
5. Consumer behavior
6. Peak load analysis
7. Rate structure optimization
8. Billing accuracy
9. Line loss identification

Addressing the data for validation problem

SLAC

Coordination with DOE projects

- Enabled by GRIP deployment/validation activities (SCE and NRECA)
- Based on LoadInsight product (courtesy PresencePG)
- Second round of TCF funding for LoadInsight will be proposed Sep 2020

Access to full-scale utility data

- Joint SCE cloud deployment of HiPAS and OpenFIDO
- Access to SCE data within SCE cloud environment
- Formal validation scheduled to begin Oct 2020 and continue through 2021

OpenFIDO Next Phase of Development

Next Phase Deliverables

1. Data Pipeline Platform

   Completed production version of data pipeline platform and workflow management tools

2. Data Visualization Tooling

   Completed production version of plot viewer prototype and suite of visualization tools

3. Extensibility Framework

   Document plugin and extensibility endpoints enabling development of third party plugins and the creation of new analysis and visualization tools

OpenFIDO Next Phase of Development

SLAC

Next Phase Deliverables

4. Customer Technical Environment Support

   Completed development of containerized architecture supporting Cloud and On-Premise deployment scenarios targeting customer technical environments.

Question for the TAC

1. **What 3 target use-cases should we focus on for March 2021?**

2. **Who would like to participate in OpenFIDO validation efforts next year?**

Thank You

Contact: dchassin@slac.stanford.edu

HiPAS GridLAB-D

TAC Meeting #5 (September 2020)

EPC 17-043 GLOW

EPC 17-046 HiPAS

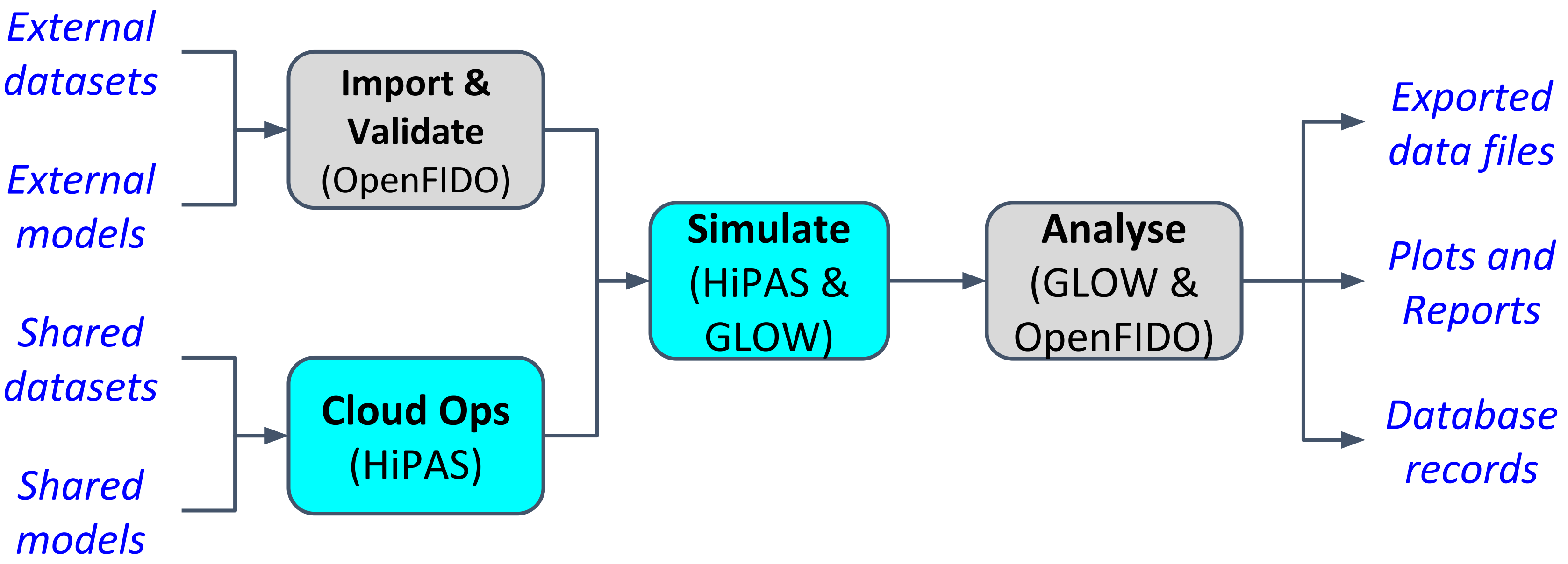
EPC 17-047 OpenFIDO

This presentation was prepared with funding from the California Energy Commission under grant EPC-17-046. SLAC National Accelerator Laboratory is operated for the US Department of Energy by Stanford University under Contract No. DE-AC02-76SF00515

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Project Focus Area



Project Objectives

SLAC

Enhance GridLAB-D to support leading California use-cases

1. Integration Capacity Analysis - Support GLOW (in progress)
2. Resilience - GRIP analytics (substantially complete)
3. Tariff design - Powernet With Markets and revenue analysis (in progress)
4. Electrification - Enable decarbonization simulations (done)

HiPAS Enhancements Completed

High-performance simulation

- Powerflow solver link with Python (links to external solvers)
- Parallel initialization, AWS operations, Python API/Library

Improved data processing tools

- Basic file input/output (“any data, any format, anywhere”)
- New database module (e.g., InfluxDB, Amazon RDS)

New simulation modules/classes

- Industrial loads (NERC-supported NAICS facilities)
- Residential loads (RBSA)
- Commercial loads (CEUS)
- Revenue module (existing PG&E tariffs and billing classes)

HiPAS Enhancements in Development

High-performance simulation

- Machine learning powerflow solvers using LR, NN, and SVR

Improved data processing tools

- Advanced file input/output (“any model, anytime, anywhere”)
- New database module (e.g., InfluxDB, Amazon RDS)

New simulation modules/classes

- Residential loads (physics-based multi-family residences)
- Commercial loads (physics-based commercial buildings)
- Revenue module (existing SCE and SDG&E tariffs, tariff analysis)

HiPAS Enhancements Coming Next Year

High-performance simulation

- Granular parallelization for all events (including python events)
- Integrated ML powerflow solver
- Remote job control, GCP/Azure operations

Improved data processing tools

- Completed OpenFIDO integration (data and models)

New simulation modules/classes

- Industrial loads (non-NERC NAICS facilities)
- Residential and commercial loads (census-based/AMI-fit models)
- Tariff design and electrification use-cases

Data-driven physics-based building models

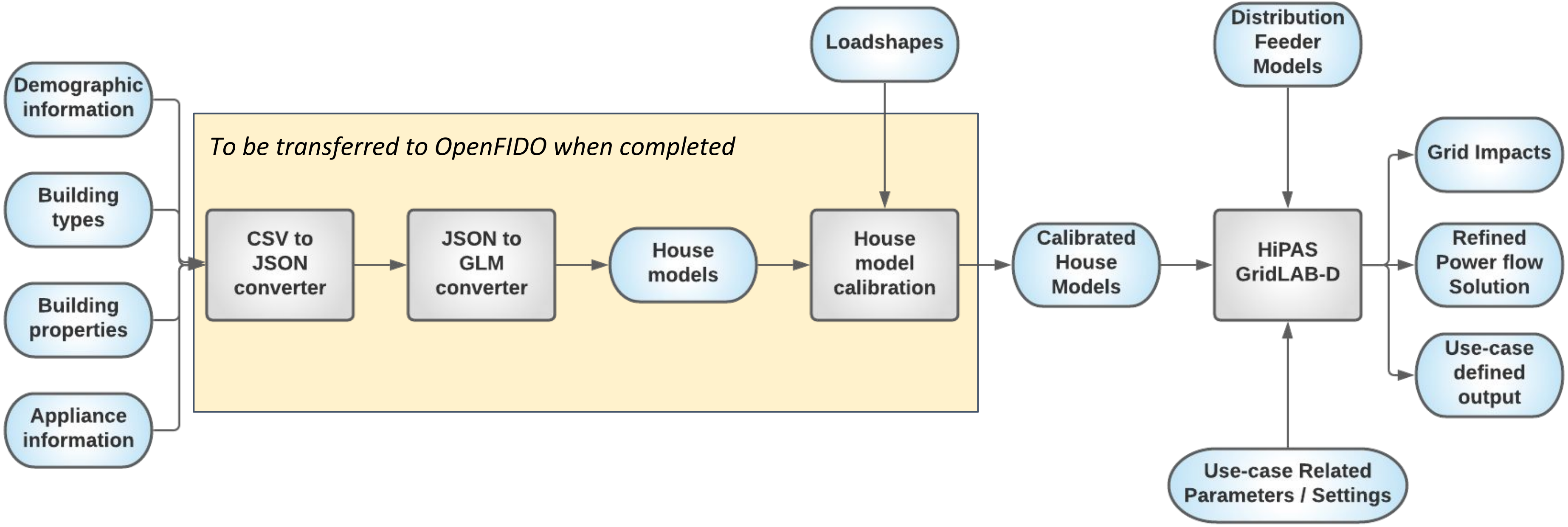
Census data contains descriptive properties of houses:

- Types of housing, e.g., multi-unit, stand-alone, etc.
- Floor area, construction vintage, construction quality
- Appliances and fuel type (i.e., gas, electric)

Generate building models in distribution system

- Next step: calibrate buildings to energy and loadshape

Data-driven physics-based building models



Highlights: Cloud deployment

SLAC

GitHub deployment

- Source code: http://source.gridlabd.us/
- Integrated online documentation at http://docs.gridlabd.us/

Docker containers maintained/updated automatically

- Docker hub repository located at http://docker.gridlabd.us/

CircleCI free tier operations

- Any github project can run HiPAS GridLAB-D on CircleCI for free
  - Latest master release: *slacgismo/gridlabd:latest*
  - Release candidate: *slacgismo/gridlabd:develop*

Machine Learning Powerflow In Depth

Lily Buechler, Stanford University
(ebuech@stanford.edu)

Adithya Antonysamy, Siobhan Powell, Ram Rajagopal (Stanford University), and Tom Achache (Columbia University)

Machine Learning-Based Power Flow Estimation

SLAC

Power Flow simulation in GridLAB-D

- 3-phase, unbalanced, quasi-steady power flow
- Map power injections to voltages via inverse power flow mapping

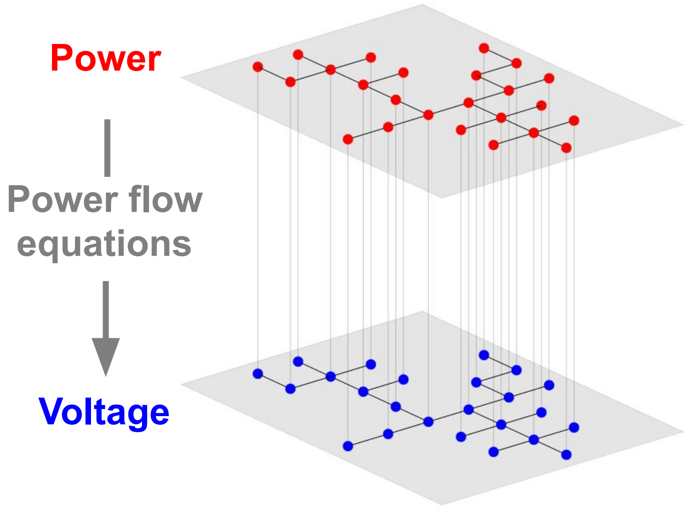
Standard approach

- Newton Raphson (NR) with the current injection method
- Computationally expensive for large networks

Data-driven approach

- Build machine learning-based mapping using previous NR solutions
- Adaptively select when to utilize machine learning vs. Newton Raphson solver
- Update data-driven model online with new measurements

Inverse power flow mapping



ML Models and Test Cases

Model Types:

- *Regression-based models*
  - Regularized linear regression
  - Quadratic regression
  - Piecewise linear regression
  - Recursive least squares filter
- *Deep learning-based models*
  - Fully-connected neural network
  - Input-convex neural network
- *Support vector regression*

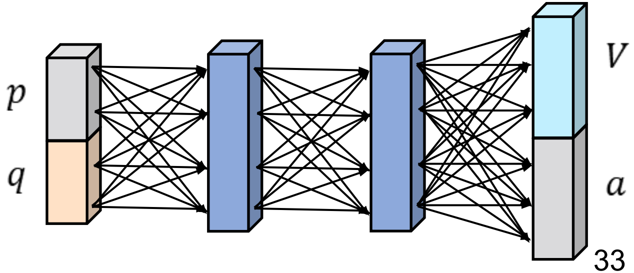
Network scenarios and model tuning:

- Network loading level
- Network size
- Model hyperparameters
- Amount of training data

Power system test cases

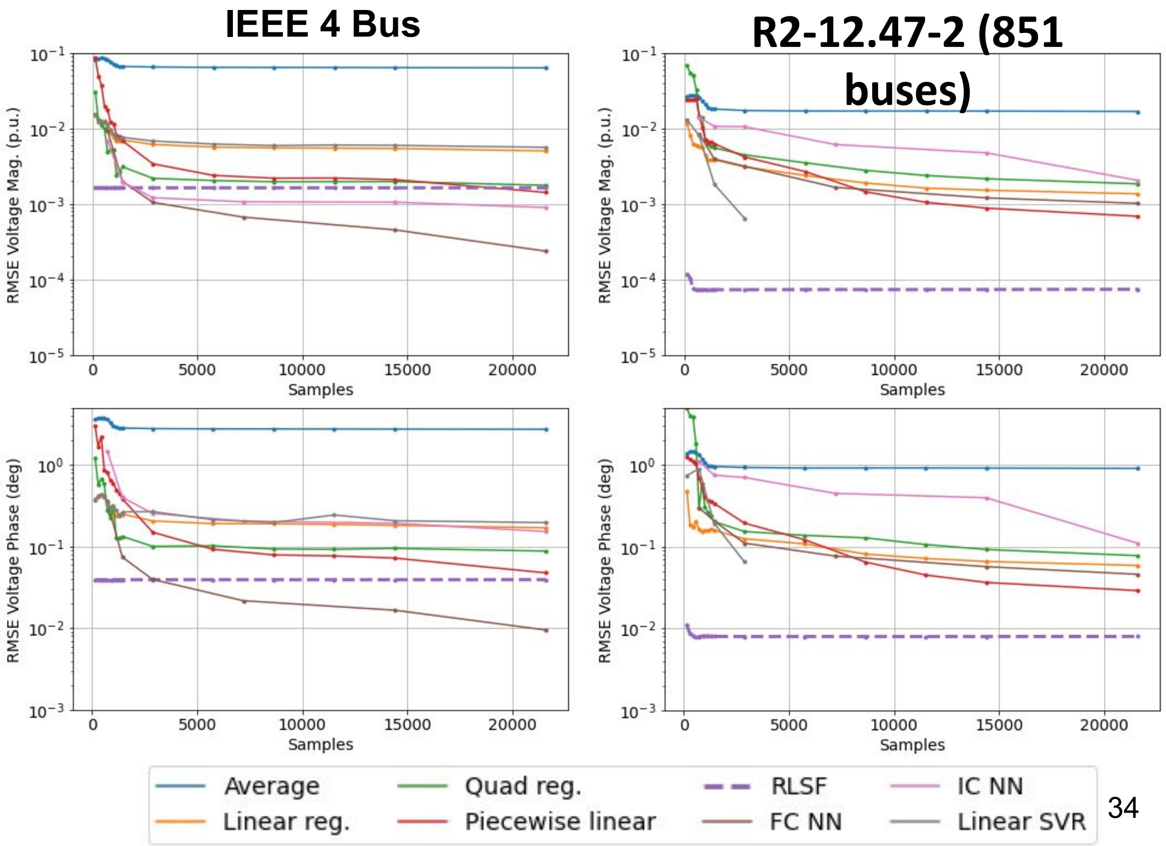
Network	Primary voltage (kV)	Voltage (output) dimension	Power (input) dimension
IEEE 4	12.47	12	3
IEEE 13	4.16	48	20
IEEE 123	4.16	402	95
PNNL GC-12.47-1	12.47	108	9
PNNL R1-12.47-3	12.47	297	20
PNNL R2-12.47-2	12.47	2553	22

Fully-connected neural network



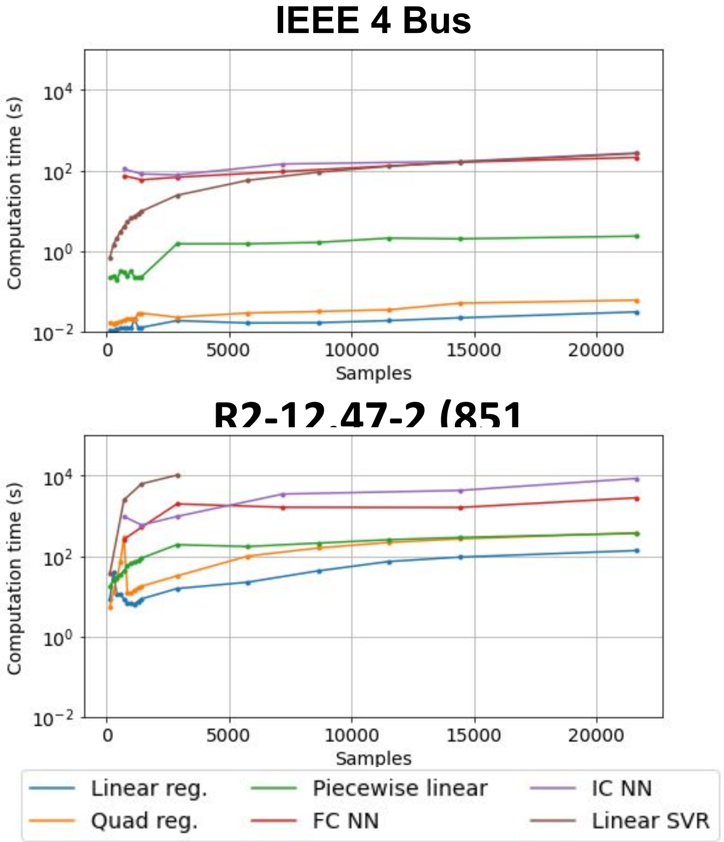
Benchmarking Model Performance - Accuracy

- **Recursive least squares filter**
  - Computationally and memory efficient and adapts well to changing grid conditions
- **Deep learning approaches**
  - Good performance for small networks but has high data requirements and less scalable
- **Linear regression**
  - Performance is good for low loading, degrades for high loading



Benchmarking Model Performance – Computational Cost

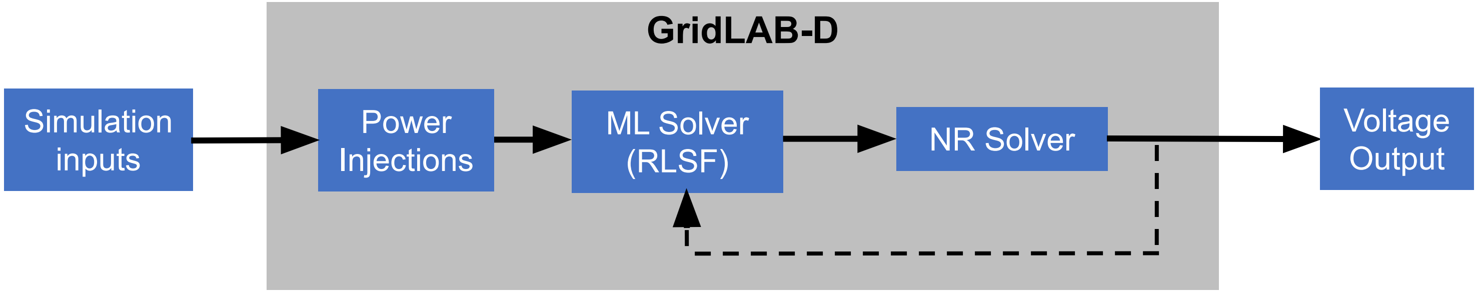
- **Recursive least squares filter**
  - Computationally and memory efficient and adapts well to changing grid conditions
- **Deep learning approaches**
  - Good performance for small networks but has high data requirements and less scalable
- **Linear regression**
  - Performance is good for low loading, degrades for high loading



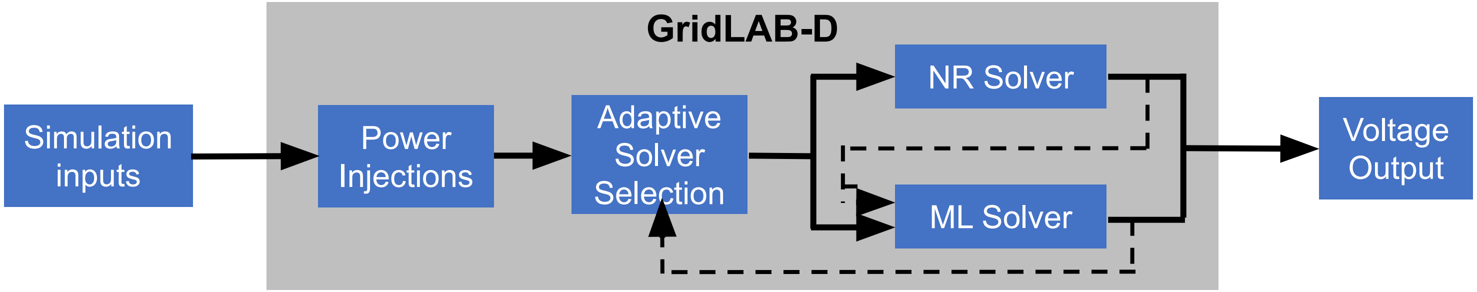
Algorithms for Online Solver Implementation

SLAC

Newton Raphson solver seeding with ML model



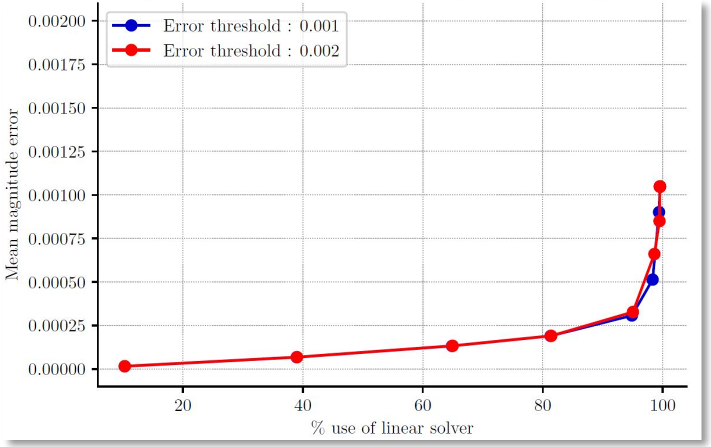
Adaptive NR/ML Solver

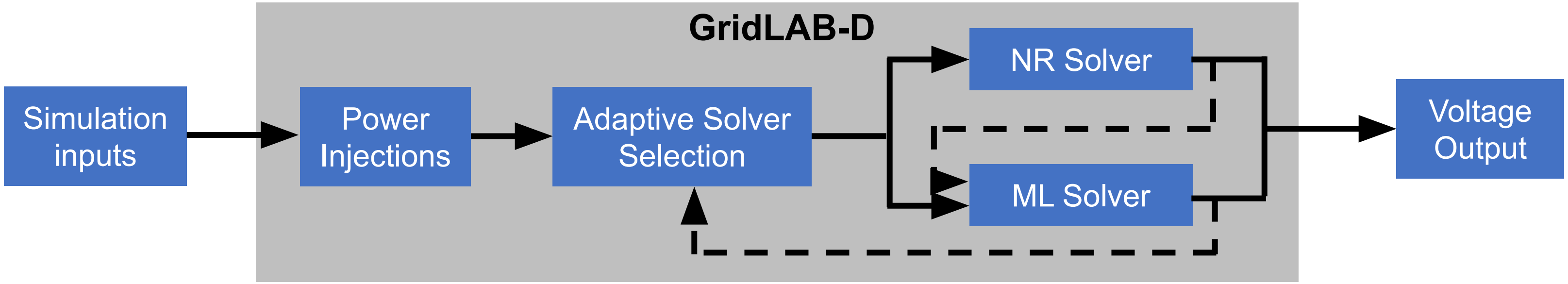


Preliminary Results on Solver Deployment

- Train ML model online during simulation using input/output of NR solver
- Adaptively select between using standard NR solver and ML solver based on inputs and previous errors
- There is a tradeoff between the amount of ML solver use and total error rate

ML solver use vs. voltage magnitude error





Next Steps

Additional ML model validation

- Benchmark model performance on additional networks and loading scenarios
- Investigate additional physics-inspired architectures
- Learn control actions of capacitor banks and voltage regulators

Online GridLAB-D ML solver implementation

- Implement recursive least squares filter for Newton Raphson seeding
- Select model framework for adaptive ML/NR solver and implement

Online algorithm performance evaluation

- Test recursive model updating to adapt to load and topology changes
- Document overall computational speedup

TAC Questions

Do you see any new use cases emerging that we should know about?

- We may not be able to support new use-cases soon
- But we'd like to consider what's coming

What is your view on cloud operations?

- We support most host/enterprise/cloud ops model
- Now is a good time to make last-minute adjustments

Thank You

Contact: dchassin@slac.stanford.edu

GridLAB-D Open Workspace (GLOW) Project Update

09.11.20

Bo Yang, Ph.D.
Yanzhu Ye, Ph.D.
Joseph C., Ph.D.
Abe Masanori

Hitachi America, Ltd

GLOW Overview

GridLAB-D Open Workspace (GLOW) is a project to deliver a web-based graphical user interface for GridLAB-D. The open-source user interface aims to augment GridLAB-D in a more intuitive, user friendly manner, contributing to wider use of the simulation technology.

Hitachi aims to achieve the intuitiveness of the tool by employing human-centered design approach. The process includes defining requirements for the interface through researching the potential users, and designing the interfaces according to the discovered requirements.

Outline

- Project Plan Overview
- California ICA Implementation
- GLOW Alpha Release and Live Demo
- Next Step – Alpha Test

Project Plan Overview

Project Plan - Overview

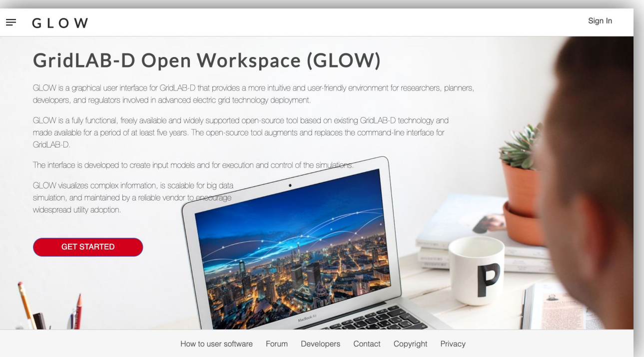
HITACHI
Inspire the Next

Task 3: Implementation

April, 2020 – September, 2020

- GLOW architecture design
- UI blueprint design
- UI prototype implementation
- Backend implementation
- Unit test on IEEE feeders
- GridLAB-D integration (HiPAS NOT included)

❑ Unit test on industry feeders (not fully tested on PG&E taxonomy feeders)
❑ OpenFido integration



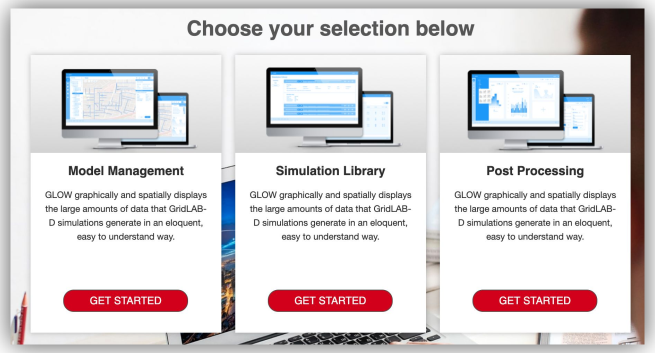
Task 4 : Production Test

Sep 2020 – Sep 2021, Alpha test (usability with designed features) : Last open call for major feature proposals
Sep 2021 – Sep 2022, Beta test (performance for society users) : Scalability and robustness enhancement

Project Plan - Overview

GLOW Alpha release

Objective: robust framework with basic functionalities and acceptable computational performance



Available Features:

- ✔ Load GridLAB-D dataset for power flow simulation
- ✔ Graphic view of models
- ✔ Edit, add or delete feeder components
- • Load simulation results to create charts and report pages – Based on predefined chart template
- • CA ICA analysis, tested on IEEE 123 – Benchmarking with SCE results
- ✔ Basic user access control and workspace management
- ✔ Unit test for GLOW components
- ✔ GLOW.Alpha release on AWS

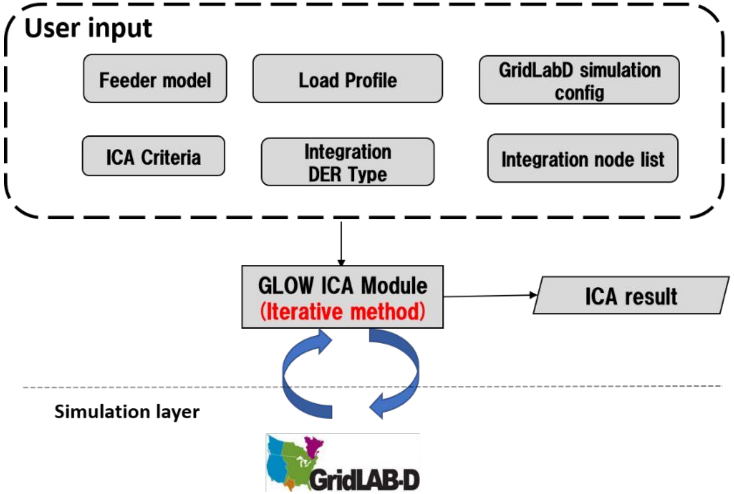
• Ongoing deeper efforts than project required
✔ Completed minimal viable features

California ICA Implementation

GLOW ICA Implementation

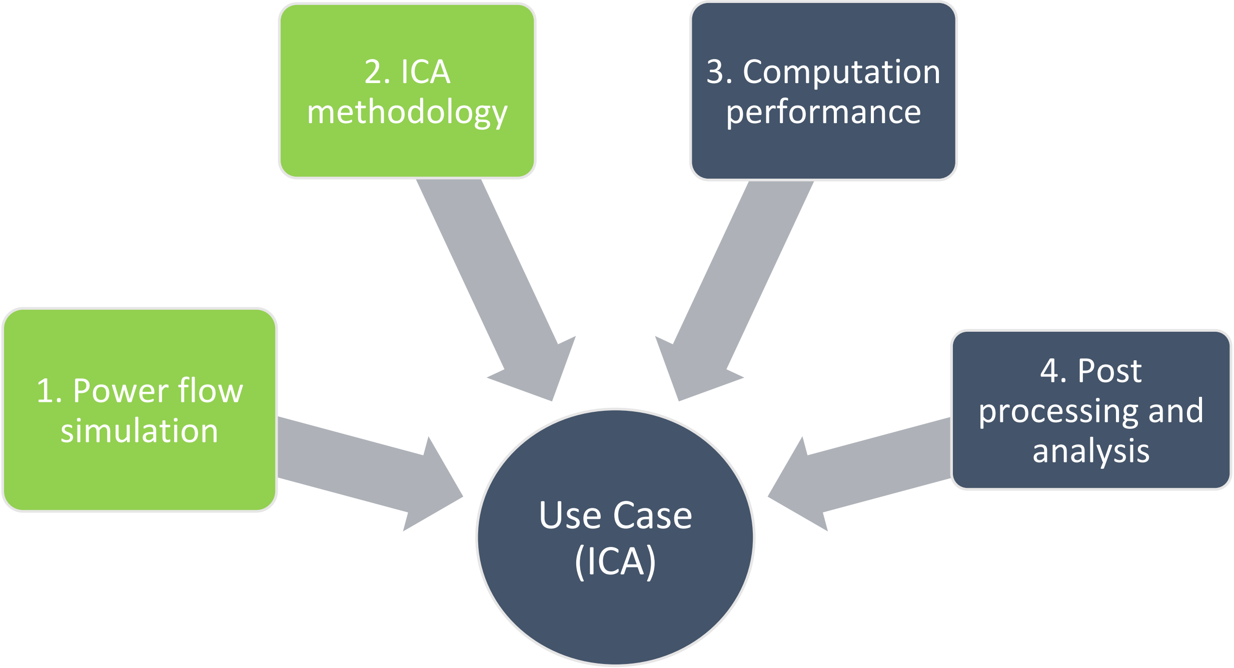
HITACHI
Inspire the Next

- Objective:
  - Identify the maximum DER capacity that can be integrated onto distribution system down to the line section or node level without compromising its reliability and power quality.
- GLOW ICA implementation
  - Iterative method – defined in CPUC report
  - Binary search – Hitachi methods to speed up the simulation
  - Graphical user-friendly simulation set-up wizard



- Tabular report detailing maximum hosting capacity at each node for each individual constraints
- Color-coded one-line diagram

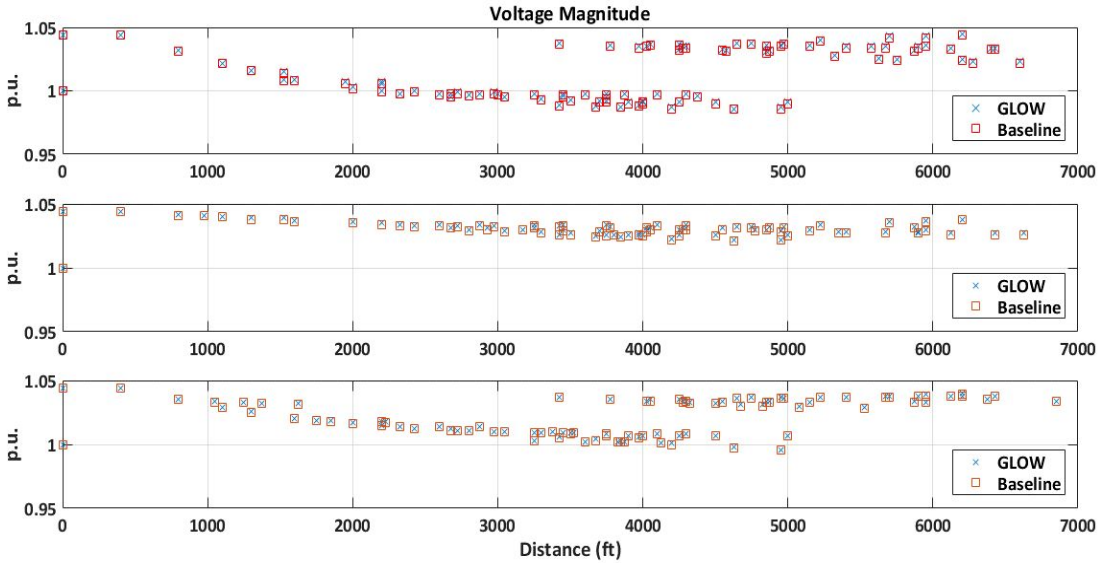
GLOW simulation benchmark



Does GLOW power flow meet industry standards?

GLOW (GridLAB-D) v.s. IEEE 123 Bus datasheet (published by IEEE PES)

- Three-phase node voltages match well



	Phase-A	Phase B	Phase C	Total
Avg absolute difference (%)	**0.088**	**0.087**	**0.069**	**0.079**

IEEE123-bus feeder: https://site.ieee.org/pes-testfeeders/resources/

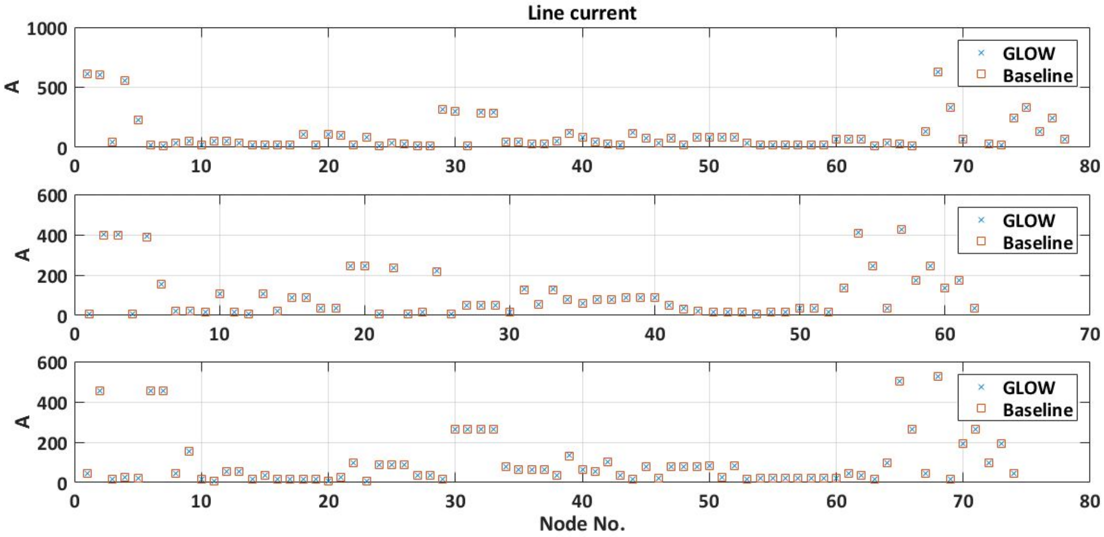
Does GLOW power flow meet industry standards?

HITACHI
Inspire the Next

GLOW (GridLAB-D) v.s. IEEE 123 Bus datasheet

- Three-phase line current matches well
- Total feeder power matches well

✔ **GLOW power flow comparable to industry standards**



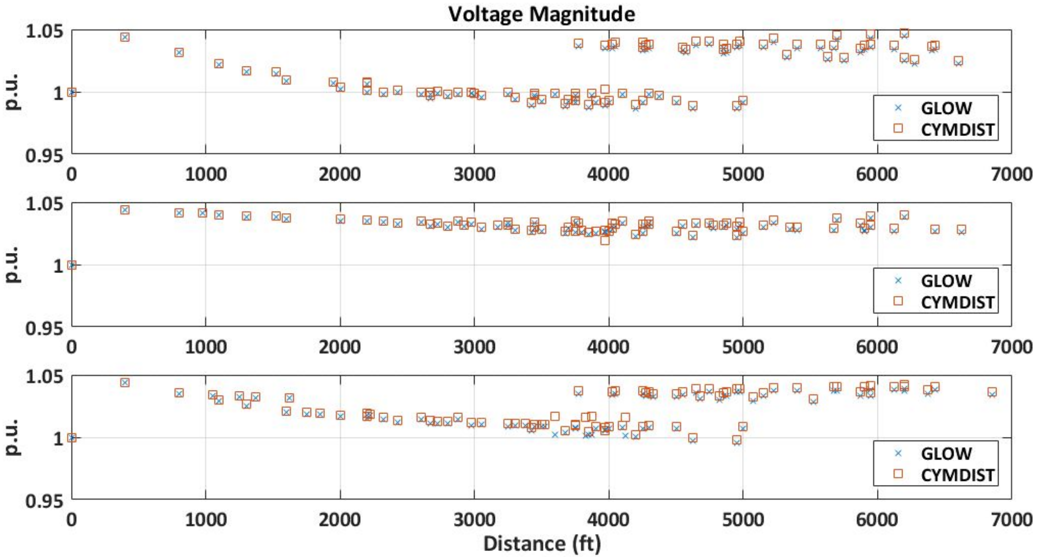
	Phase-A	Phase B	Phase C	Total
Average abs difference (%)	**0.95**	**0.84**	**0.25**	**0.68**

Total feeder-in power difference (%) : **0.55%**

Does GLOW power flow comparable to other tools?

GLOW(GridLAB-D) v.s. CYME model (SCE IEEE 123 bus network)

- Three-phase node voltages match well



	Phase-A	Phase B	Phase C	Total
Avg absolute difference (%)	**0.23**	**0.14**	**0.27**	**0.22**

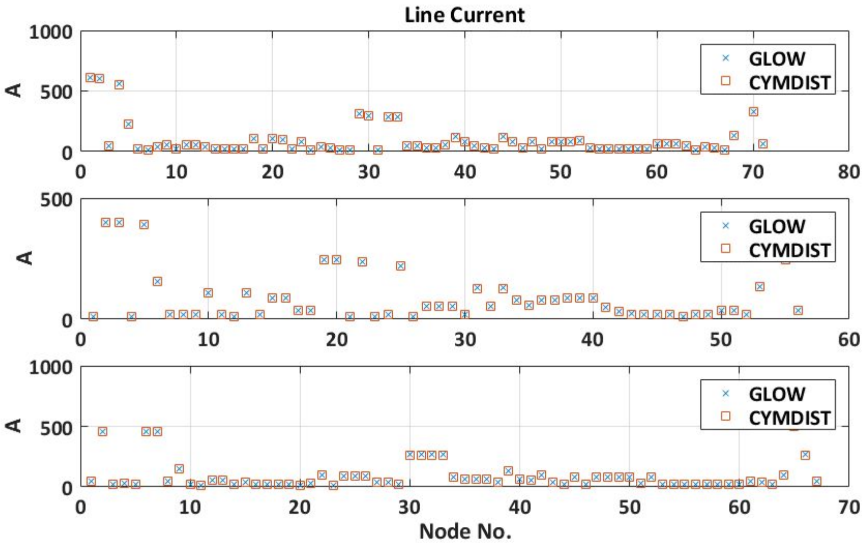
Does GLOW power flow comparable to other tools?

HITACHI
Inspire the Next

GLOW(GridLAB-D) vs. CYME model (SCE IEEE 123 bus network)

- Three-phase line current matches well
- Total feeder power matches well

✔ <u>GLOW power flow comparable to industry tool (CYMDIST)</u>



	Phase A	Phase B	Phase C	Total
Avg absolute diff (%)	**0.98**	**0.88**	**0.40**	**0.75**

Total feeder-in power difference (%) : **0.32%**

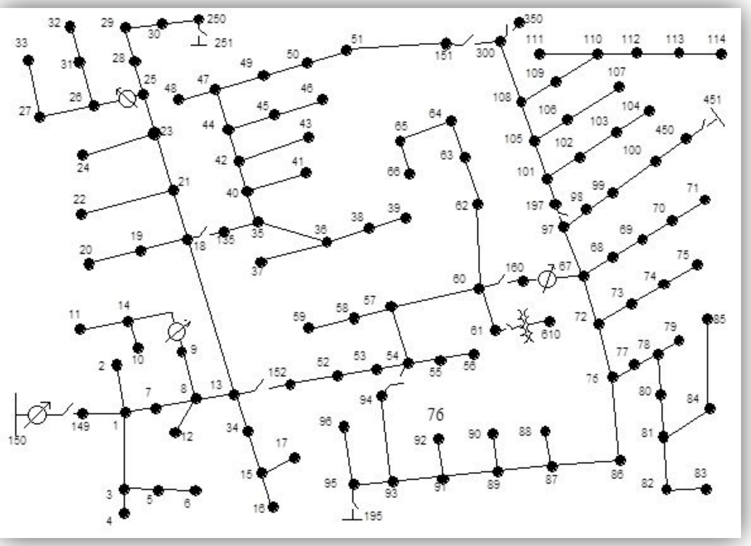
Does GLOW ICA match other tools?

HITACHI
Inspire the Next

- **Model**: IEEE 123 node system
- **Tools**: GLOW vs. CYMDIST
- **Methodologies**:
  - GLOW ICA Module
  - CYMDIST ICA Module
- **ICA Settings**
  - DER Type: Generation
  - Three-phase nodes
  - Maximum integration capacity: 50,000 kW
  - Tolerance: 1kW
  - ICA criteria

    Voltage limit: 95%-105%

    Voltage fluctuation: <3%



IEEE 123 node feeder model

Does GLOW ICA match other tools?

HITACHI
Inspire the Next

- GLOW and CYMDIST ICA results are well aligned

- IC value differences may be caused by different ways of system modelling, load flow calculation, and so on in these two tools.

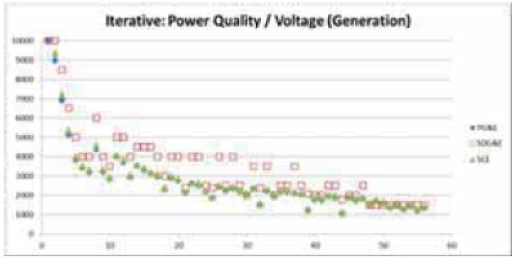
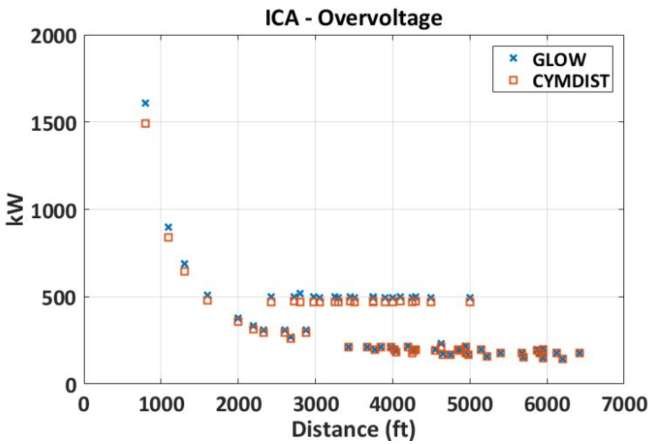
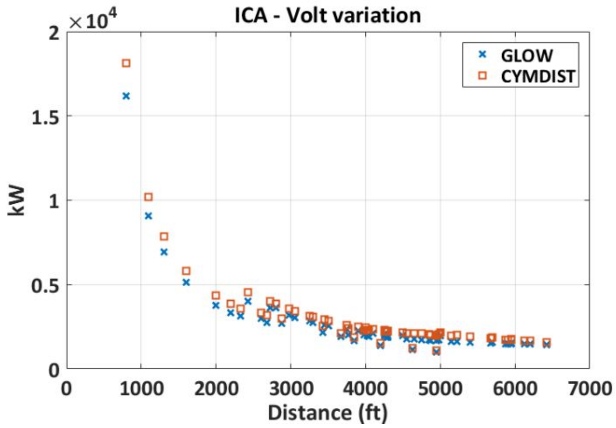


FIGURE 50: ITERATIVE PQ IC COMPARISON

Figure. ICA Comparison from three IOUs using CYMDIST and SynerGEE [1]





[1] SCE Demonstration Projects A and B Final report, https://drpwg.org/wp-content/uploads/2016/07/R1408013-SCE-Demo-Projects-A-B-Final-Reports.pdf

Interesting observations : ICA results are sensitive to settings

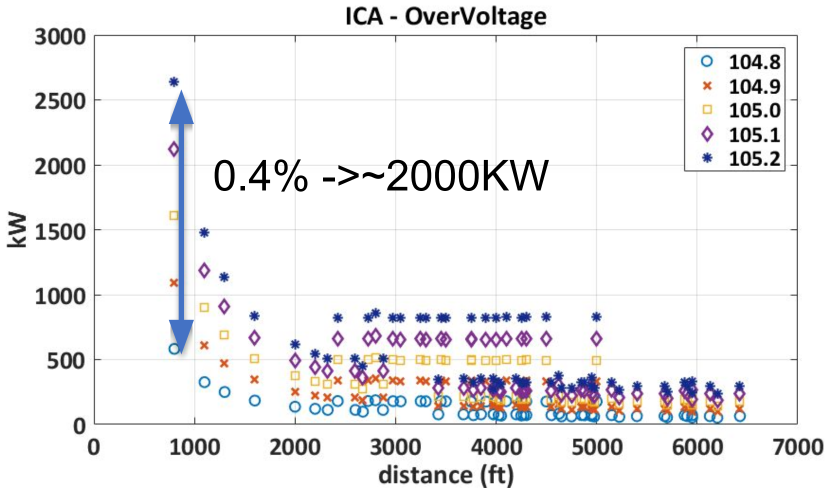


Figure. IC value (overvoltage) under different voltage limit - GLOW

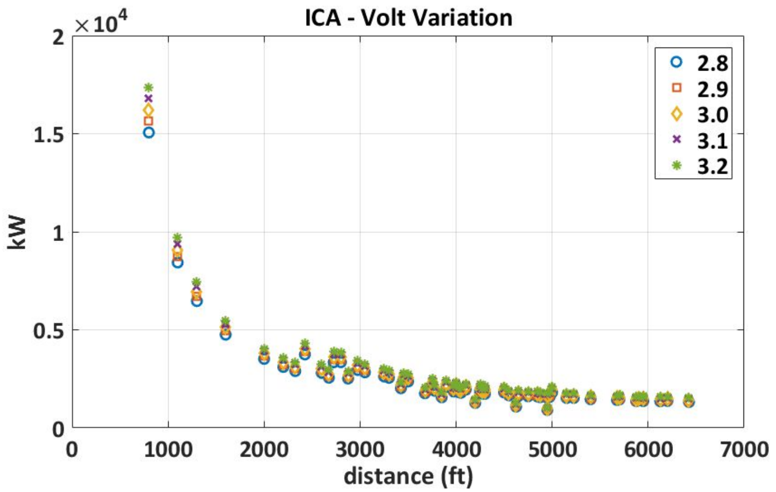


Figure. IC value (volt variation) under different volt variation limit - GLOW

- For over-voltage criteria, 0.1% threshold deviation from 105% will cause up to 30% integration capacity changes.
- For voltage fluctuation criteria, the integration capacity is less sensitive to threshold variation, 0.1% threshold variation from 3% causes ~3% capacity changes.

Interesting observations : Also in CYMDIST

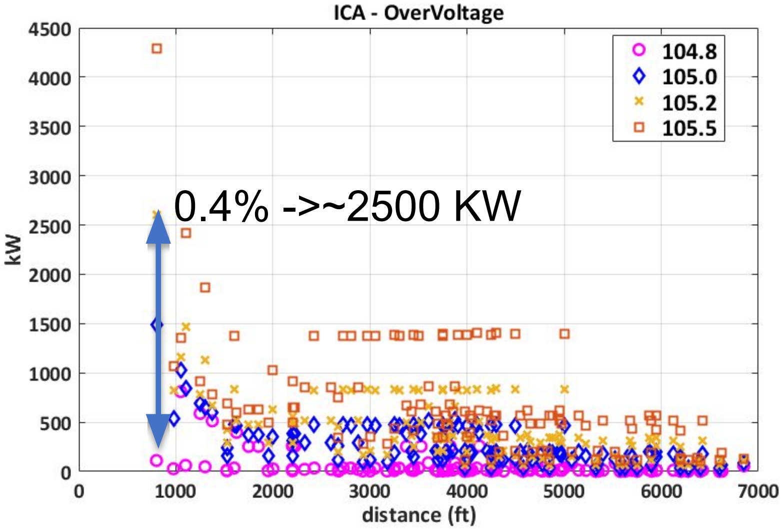


Figure. IC value (overvoltage) under different voltage limit - CYMDIST

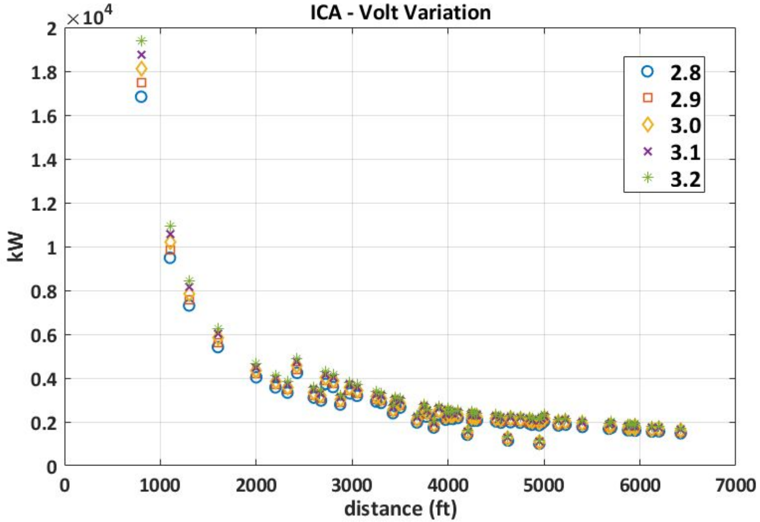


Figure. IC value (volt variation) under different volt variation limit - CYMDIST

- Similar sensitivity also observed in CYMDIST ICA simulation.

ICA Conclusions and Questions

- GLOW (w. GridLAB-D) is a power flow analysis tool that can generate results comparable to industry standards

- GLOW ICA (California) implementation is aligned with CYMDIST ICA implementation and comparable to published results in CPUC demonstration project reports.

- Questions:
  - How sensitive are other ICA modeling tools and methods to variation in violation thresholds?
  - How has this sensitivity been managed?

Next Step

- Testing and benchmarking more **utility feeder** models
- Improve GLOW ICA computational efficiency
- Dive deeper on sensitivity analysis
- Collaborate with academic teams (NREL, ASU, SLAC) on benchmarking various popular **hosting capacity methodologies**

GLOW Alpha Release and Demo

GLOW Alpha Release and Demo

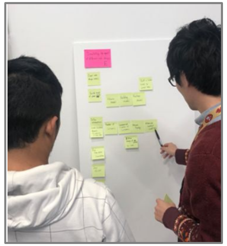
HITACHI
Inspire the Next

- Previous activities
- Information Architecture
- Live Demo
  - Landing page
  - User Management
  - Scenarios
    - Create a model based on a GridLAB-D without Coordinates
      - Visualize a model in a viewer
    - Create a model based on a GridLAB-D with Coordinates
      - Visualize a model in a viewer
      - Create and run power flow simulation
      - Create charts based on result from power flow

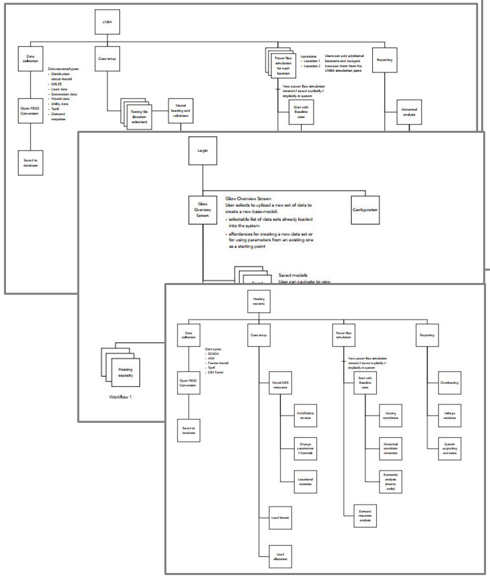
Previous Activities

HITACHI
Inspire the Next

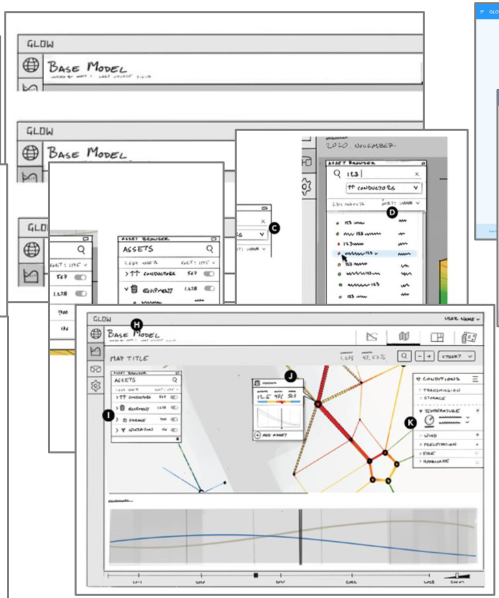
Human-centered design approach.



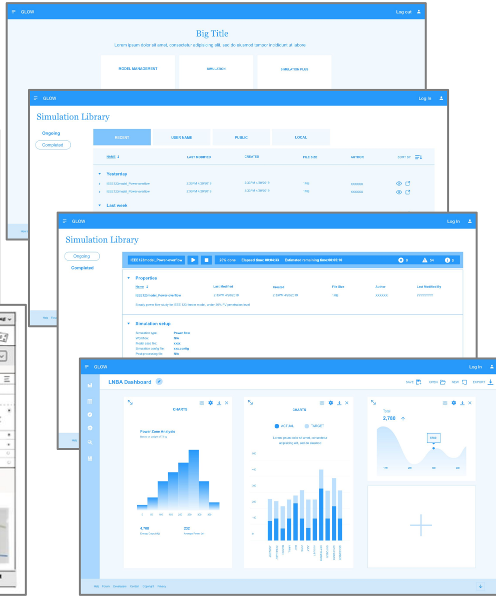
Task Flows



Sketches



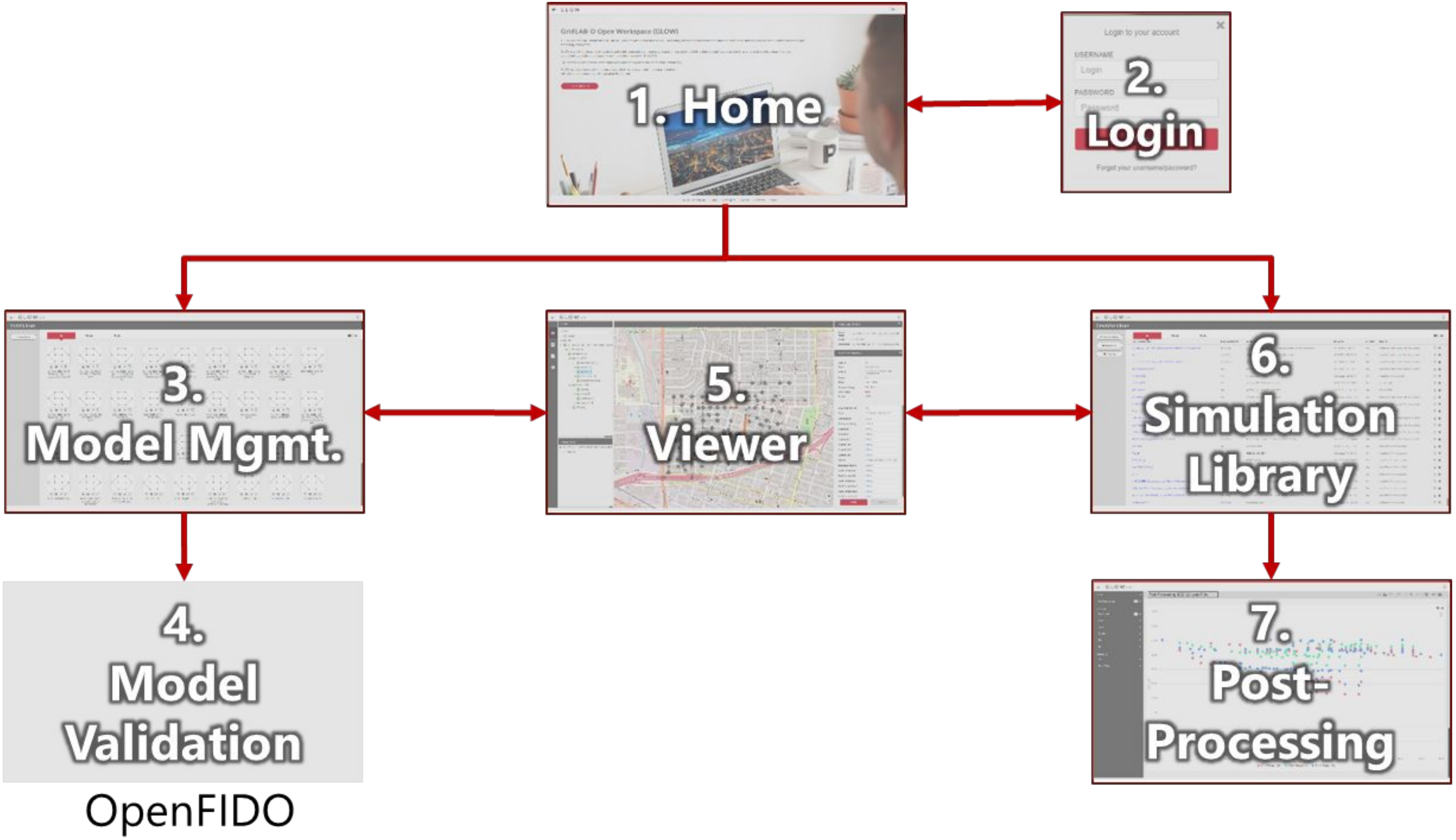
Wireframes



Requirements

ID	Section	Requirement	Note
1.0.0	Main		
1.1		Home	Link to home
1.2		Model Management	link to model management
1.3		Simulation Library	link to simulation library
1.4		Post Processing	Link to post processing
3.0.0	Viewer		
3.1.0	Menu		
1		Icon to open menu	
2		Icon to close or collapse "Menu Bar"	
3		Mouse over any icon to display text description	
4		Click menu icon to open "Menu Bar"	
5		This action will grey out other area	
6		Standardize across every module to provide access to other modules	
3.2.0	Side Bar and Panel		
1		Side Bar contains icon to show panel (1) Layers	
2		Mouse over any icon to display text description	
3		Click any icon on "Side Panel Icon Bar" to open Panel Window	
4		Icon is highlighted or circled to show active status	
5		Click any icon again to close "Panel" Window	
6		User can adjust the width of any panel	
7		If there are more than 1 panel open, user can adjust the height of each panel	
8		Arrow to hide side panel windows	
9		Map view to keep the same zoom level and coordinate when a panel is opened	Map View
3.3.0	Map View		
1		Split view for (1) Map for object with coordinate and parent child relationship and (2)	
2		User can change size of frame for split frame	
3		Frame 1 - Display open network/model/layers of map, feeder, equipment	
4		Switch to select	
5		Frame 1 and 2 - Include "Navigation Bar" within a map view (This can be place	
6		Zoom in / out	
7		Pan	
8		Show information panel - Click Information Icon and then click any item on a map	Other implementation that provide similar functionality is ok
9		Identify data of equipment by double click on a mouse	Other implementation that provide similar functionality is ok
10		Toggle button to switch between map view and List view	List view may not be implemented
3.5.0	Layer Panel		
1		Click on "Layers Panel" icon on the side panel window to open "Layers Panel".	
2		Tree structure	

GLOW Information Architecture



Live Demo

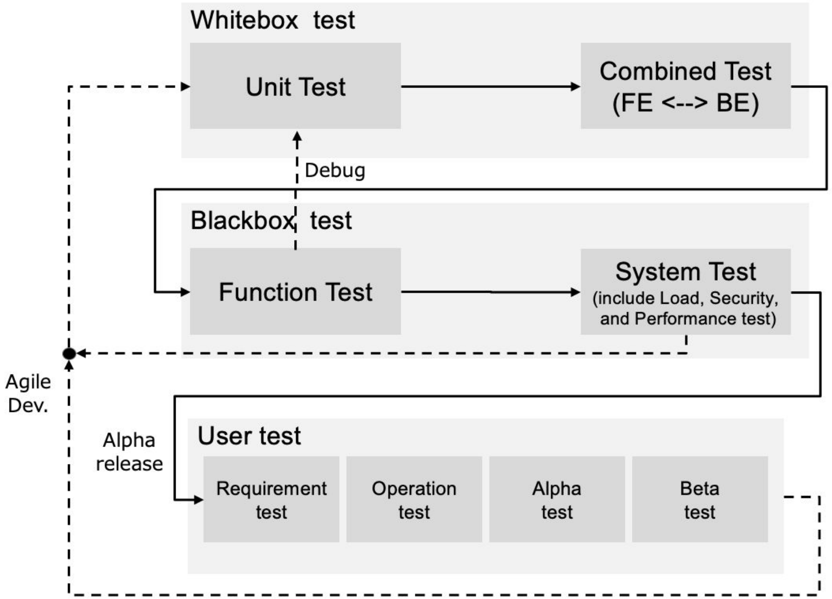
Next Step – Alpha Test

Alpha Test - Methodology

Alpha Test Objective

Sep 2020 – Aug 2021

- Validate GLOW alpha implementation
- Identify other must-have features (bounded by project schedule and resource)
- Benchmark computational performance (GLOW & HiPAS)
- Prepare industry equipment library (optional)



Alpha test is the last open call for major features proposals

Alpha Test – Details and Benefits

Last Call for "Must-Have Features"

Sep 2020 – Aug 2021

- UI features, dashboard shortcuts that can reduce simulation efforts
- Use cases that are required by company besides ICA
- Performance KPIs, including data volume, system size, computational delays etc.

Benefits to test masters

Tailored implementation

- Dashboard design tailored to needs
- **Key use cases** prioritized in implementation
- Minimal integration barrier for future adoption
- Hands on training and user experiences
- In-depth understanding to GLOW design and implementation
- Participation in use case benchmark and publications

- Alpha Test will finalize dashboard and platform implementation.
- Great opportunity for TAC members to Tailor features/prioritize development.

HITACHI
Inspire the Next

Work plan:

- **Test Master team**: 5~6 planning or ICA engineers
- **Commitment**: 2 hours each month (1 hours self validation session, 1 hours online one-on-one session)
- **Tasks**:
  - Perform planning studies using example feeders and validate answers (IEEE and PG&E test feeders in GLM format)
  - Identify missing features and use cases, and rank for development priority
  - Define performance KPIs
  - General usability feedbacks
- **System requirements**: computer with internet connection, chrome browser

GLOW development team plans to issue monthly software updates

Asks to TAC

Propose **Test Masters** to represent your entity

Look for representative **industry feeder models** to test run and benchmark performance

Thank You

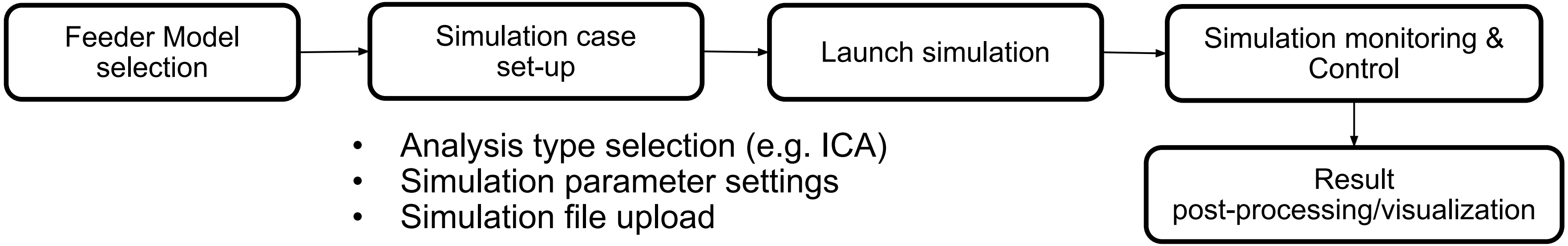
- California Energy Commission
- California Public Utility Commission
- South California Edison
- Pacific Gas & Electric
- Sunrun

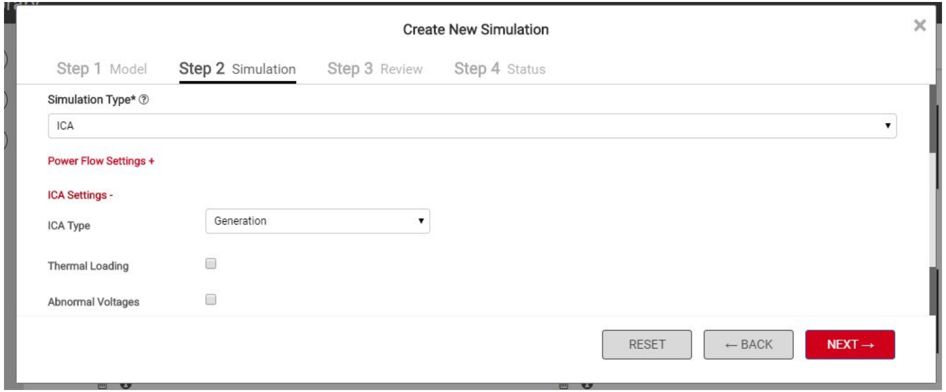
HITACHI
Inspire the Next

GLOW ICA Workflow

- User-friendly simulation set-up wizard

Pre-designed workflow template to select model, set-up ICA analysis, run analysis and export/analyze results.





GLOW solution architecture

HITACHI
Inspire the Next

Features

- A data platform designed for scalability and expandability
- Easy to integrate with 3rd party tools
- Suitable for streamlined study process
- Designed for cross-organizational collaborations

User interface
Model lib / Simulation lib / Viewer / Post-processing

API
Model Validation / Simulation Que Mgmt / Data Mgmt / Analysis / Configuration / Access Control

Data Lake
Model / Raw data / Simulation Results / User Profile

Analytical Engines Interface
OpenFido / GridLAB-D / HiPAS / GLOW

External System Interface
Load CSV / Load Forecast / AMI / DMS

Publications

- **Presentation**: Conference panel presentation for 2020 DistribuTECH conference (*SLAC, Hitachi, Gridworks, NationalGrid*)
- Original fact sheets updating to reflect lesson learned (*Gridworks*)
- One short outreach paper under preparation (*Gridworks, Hitachi*)
- Brochure design for easy communication of GridLAB-D project impact (*Gridworks*)

Thank you!

Contact:

Dr. David Chassin dchassin@slac.stanford.edu,
Dr. Bo Yang bo.yang@hal.hitachi.com,
Dr. Chongfuangprinya Panitarn Panitarn.Chongfuangprinya@hal.hitachi.com,
Hector Taverahtavera@gridworks.org