OpenDSS Training Workshop

Session IV – Applying DSS in R&D

EPRI OpenDSS Team

August 25, 2022

Agenda

Session 1: Monday Aug. 22nd 11:30AM – 1:30PM EST

- > Distribution system basics, OpenDSS basics and scripting

Session 2: Tuesday Aug. 23rd 11:30AM – 1:30PM EST

- > Intro to OpenDSS-G, New Functionality in DSS, Advanced Topics

Session 3: Wednesday Aug. 24th 11:30AM – 1:30PM EST

- > Extending Capabilities of OpenDSS via a Programming Language

Session 4: Thursday Aug. 25th 11:30AM – 1:30PM EST

- > Applying DSS in R&D

Housekeeping

You'll get all resources (presentations and scripts) in the OpenDSS repository.

Link: https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Training/Virtual-2022/

You'll know when the video recordings are available via email.

We'll post it in the SourceForge discussion as well.

You'll earn Professional Development Hours (PDH).

You've have required it during the registration.

Any questions, please contact Arin Nichols (anichols@epri.com).

You can interact with us during the meeting by using the Webex Q&A feature.

We'll try to answer as many questions as possible.

Instructors

Celso Rocha, Member, IEEE

Celso Rocha serves as Engineer Scientist II at the Electric Power Research Institute (EPRI) in Knoxville, Tennessee, USA. He holds the BSEE (2017) degree and the Master (2021) degree in Electrical Engineering with emphasis in energy and automation from University of Sao Paulo, Brazil. His work has been focused on Distribution Engineering, with a broad range of topics including DER integration, impacts and mitigation strategies assessments, active network management through optimization, DER modeling for QSTS, new planning methodologies for resiliency, and grid models generation, verification and validation from utility data repositories. He has 6 years of experience with OpenDSS, having taught several OpenDSS courses at conferences, universities and industry.

Instructor

Miguel Hernandez, Member, IEEE

Miguel Hernandez received the bachelor’s degree in electronic engineering from Universidad Santo Tomas, Bogotá, Colombia, in 2011, and the M.Sc. degree in electrical engineering from the Universidad de los Andes, Bogotá, in 2014, where he also received the Ph.D. degree in engineering, in 2018. He performs research and development as part of the Distribution Operations and Planning Department at the Power Delivery & Utilization Sector at the Electric Power Research Institute. As part of this position, he addresses challenges in electricity, including large-scale systems modeling and analysis, integration of distributed energy resources, advanced distribution automation, integration of new technologies in distribution planning, and design and validation of new approaches for system operation. Additionally, he develops computational tools to support resource-intensive applications such as simulations with a large number of scenarios, big data analysis, real-time simulations, and multi-agent simulations.

Instructor

Paulo Radatz

Paulo Radatz has worked as an Engineer/Scientist at the Electric Power Research Institute (EPRI) in Knoxville, Tennessee, the USA, since 2019. He received his Master's and Bachelors's degrees in electrical engineering, emphasizing energy and automation, from the University of Sao Paulo, Sao Paulo, Brazil. He was awarded a prize for being the best bachelor's student at the Polytechnic School of the University of Sao Paulo (2015).

His work at EPRI focus on hosting capacity, mitigation options to increase hosting capacity, time-series hosting capacity, and DER modeling for QSTS simulation. Currently, he is the leading developer of the EPRI DRIVE tool and one of the OpenDSS developers.

He has seven years of experience with OpenDSS, having taught OpenDSS in several meetings, workshops, and training, including EPRI's OpenDSS virtual training. He is the creator of the world's largest OpenDSS YouTube channel: https://www.youtube.com/PauloRadatz. Currently, he lectures about OpenDSS in the Electric Power Distribution MBA course and the Power System Analysis with OpenDSS course, both at Polytechnic School of the University of Sao Paulo.

Agenda

- **Recent EPRI's Applications**
  1. Creation of OpenDSS Models
  2. OpenDSS Applications in EPRI's OPS Lab
  3. Distribution Optimal Power Flow Tool
- **Examples of External Use**
  4. Teaching Students Distribution Modeling and Analysis using OpenDSS
  5. Application of OpenDSS in Optimal Real-Time Reactive Power Control using Smart Inverter in Distribution Network
  6. The impact of photovoltaic (PV) distributed generation on power quality of distribution network and Quantification of harmonic losses in distribution systems
  7. Real-time integrated T&D for situational awareness
- **Summary**

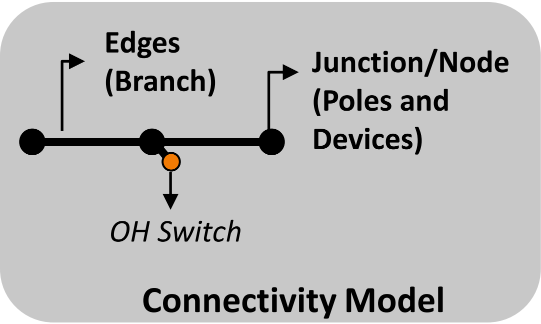
1 - Creation of OpenDSS Models

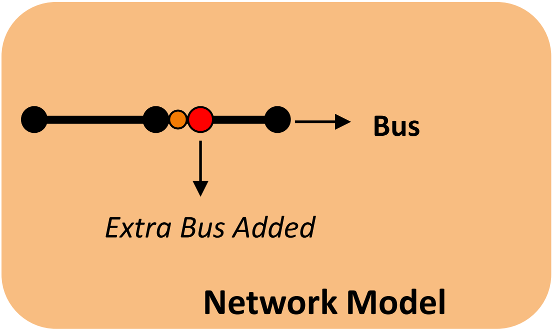
Approaches

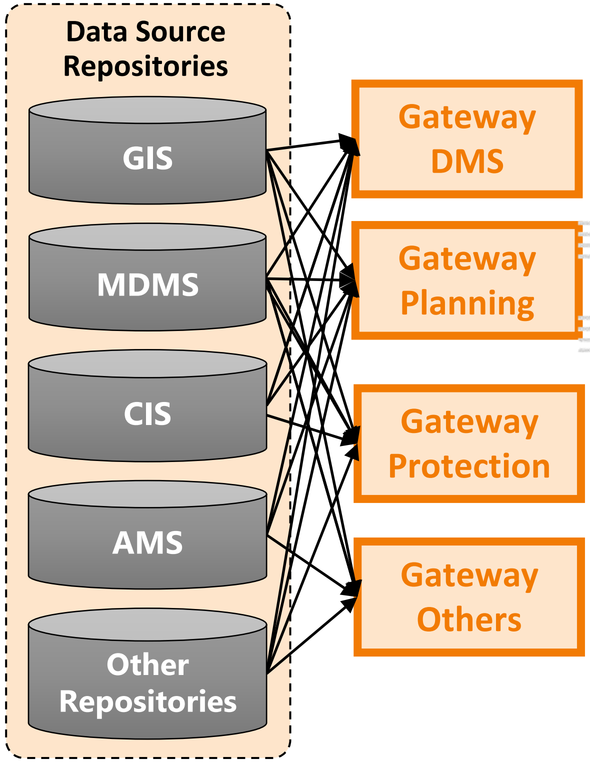
- "Write your own":
  - From GIS (and other) repositories
  - From other formats
- From existing vendor tools: CYME, Synergi, Windmill
- Publicly available model converters:
  - NREL's DiTTo
  - PNNL's CIMhub
- EPRI's experience:
  - Typically, use of in-house converters and validators for a variety of vendor tools (CYME, Synergi, Windmill, DEW, PSSE, …)
  - More recently, moving towards a unified standards-based tool

“Write your own” – From GIS and other repositories

- Challenges:
  - From a connectivity model to a network model
  - Not all required data is typically stored in the same repository
  - GIS (and other repositories) implementations are not unique
- Utilities typically resort to interfaces from the same vendors that develop the data consuming tool







“Write your own” – Other formats

- Generally straightforward as long as the data is represented in a network model format
  - For example, any of the publicly available IEEE test cases

IEEE 123 Buses

Name

- cap data.xls
- config data.xls
- ie123.tcw
- IEEE 123 Node Test Feeder Letterhead.doc
- line data.xls
- Regulator Data.xls
- spot loads data.xls
- switch data.xls
- Transformer Data.xls
- UG configuration data.xls

Line Segment Data

Node A	Node B	Length (ft.)	Config.
1	2	175	10
1	3	250	11
1	7	300	1
3	4	200	11
3	5	325	11
5	6	250	11
7	8	200	1
8	12	225	10
8	9	225	9
8	13	300	1
9	14	425	9
13	34	150	11
13	18	825	2
14	11	250	9
14	10	250	9
15	16	375	11
15	17	350	11
18	19	250	9

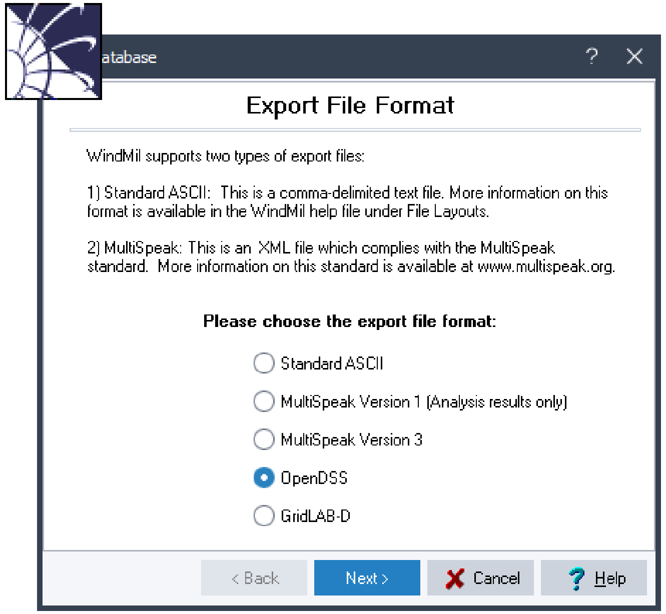
Overhead Line Configurations (Config.)

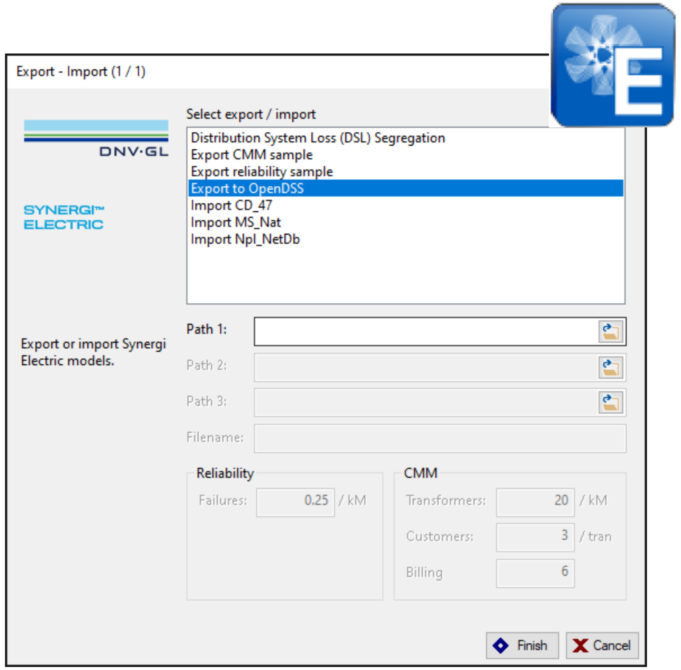
Config.	Phasing	Phase Cond. ACSR	Neutral Cond. ACSR	Spacing ID
1	A B C N	336,400 26/7	4/0 6/1	500
2	C A B N	336,400 26/7	4/0 6/1	500
3	B C A N	336,400 26/7	4/0 6/1	500
4	C B A N	336,400 26/7	4/0 6/1	500
5	B A C N	336,400 26/7	4/0 6/1	500
6	A C B N	336,400 26/7	4/0 6/1	500
7	A C N	336,400 26/7	4/0 6/1	505
8	A B N	336,400 26/7	4/0 6/1	505
9	A N	1/0	1/0	510
10	B N	1/0	1/0	510
11	C N	1/0	1/0	510

Source: https://cmte.ieee.org/pes-testfeeders/resources/

Directly From Existing Vendor Tools

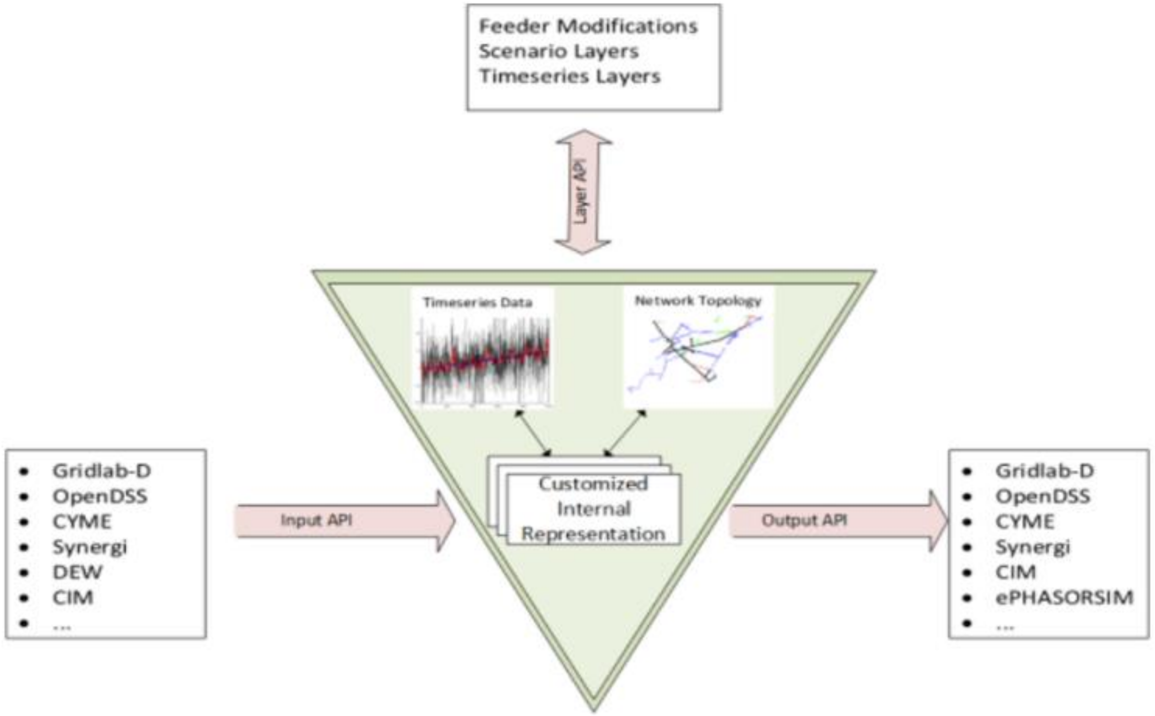
- Some vendor tools support a built-in exporter to OpenDSS
  - Synergi, Milsoft, Oracle's NMS
- Our experience:
  - Manual edits on produced OpenDSS model is commonly required
  - Effort to fix conversion issues and fine tunning the model depends on original model





Publicly Available Converters

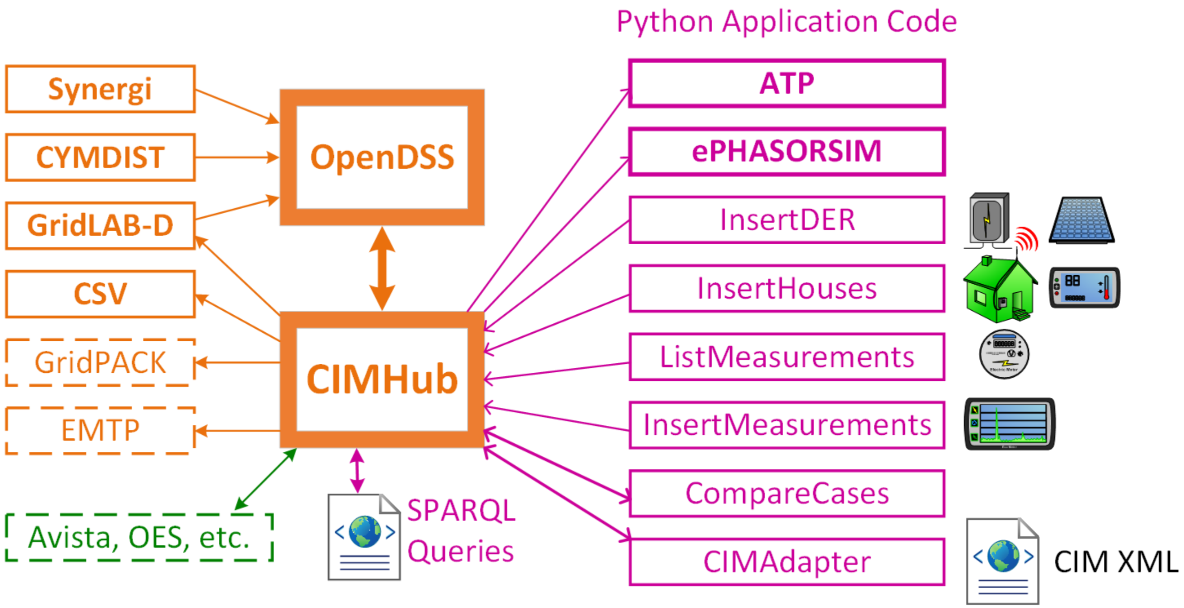
- DiTTo is a *Distribution Transformation Tool* that aims at providing an **open-source** framework to convert and modify various distribution systems modeling formats.
- Implements a ***many-to-one-to-many*** parsing framework
- Readers and writers are then implemented to perform the translation from a given format **to the core representation**, or the other way around.



Source: https://github.com/NREL/ditto

Publicly Available Converters

- *CIMHub provides **network model translation**, with two major components indicated by heavy orange blocks in the diagram below.*
- ***OpenDSS plays a central role; it creates most of our CIM XML files using its Export CIM100 command.***
- *The other heavy orange block is a Java program **that exports models from CIM XML to other formats**.*



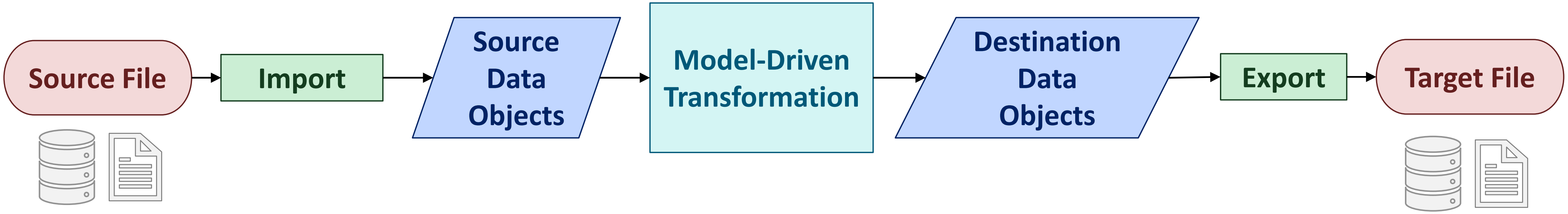
Source: https://cimhub.readthedocs.io/en/latest/Overview.html

EPRI’s Experience

- Historically, request utilities to pull GIS and other required data and EPRI would build specific translators - “Write your own”
- In the last ~10 years, used a mix between in-house tools and built-in converters from vendor tools
  - Allows validation of the generated OpenDSS models
- More recently, transitioning to a standards-based in-house tool: *EPRI Model Conversion Tool (MCT)*

EPRI Model Conversion Tool (MCT)

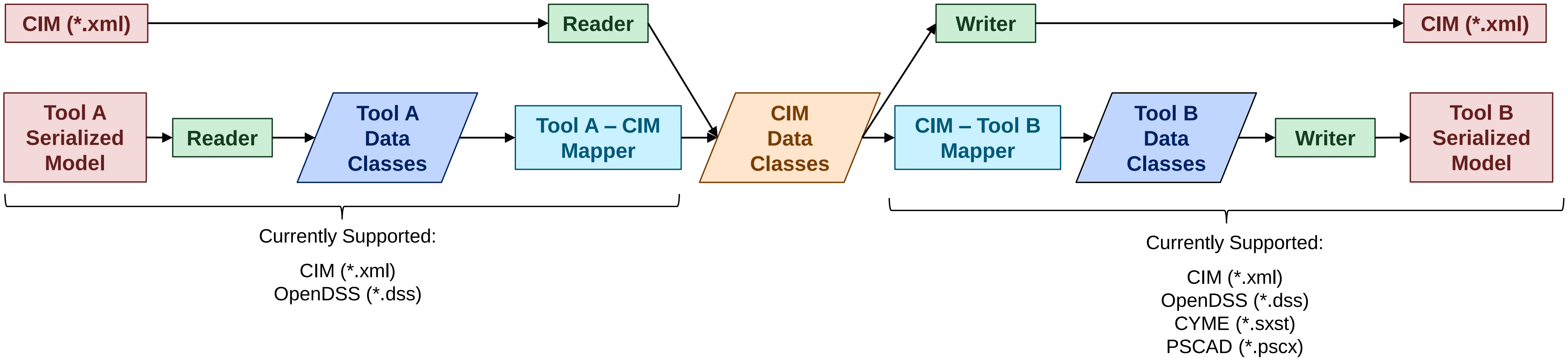
- A standalone tool developed to perform model conversion between multiple modeling tools and formats
- Many-to-many conversion (e.g., CIM to OpenDSS, DSS to CYME, CYME to DSS, …)
- Follows the **Model-Driven Transformation (MDT)** architecture



For more info on CIM and Model-Driven Transformations: EPRI's publicly available CIM Primer

EPRI Model Conversion Tool (MCT)

- CIM-based internal information model integration



For more info on CIM and Model-Driven Transformations: EPRI's publicly available CIM Primer

2 - OpenDSS Applications in EPRI's OPSLab

EPRI Operations, Protection, and Systems Laboratory

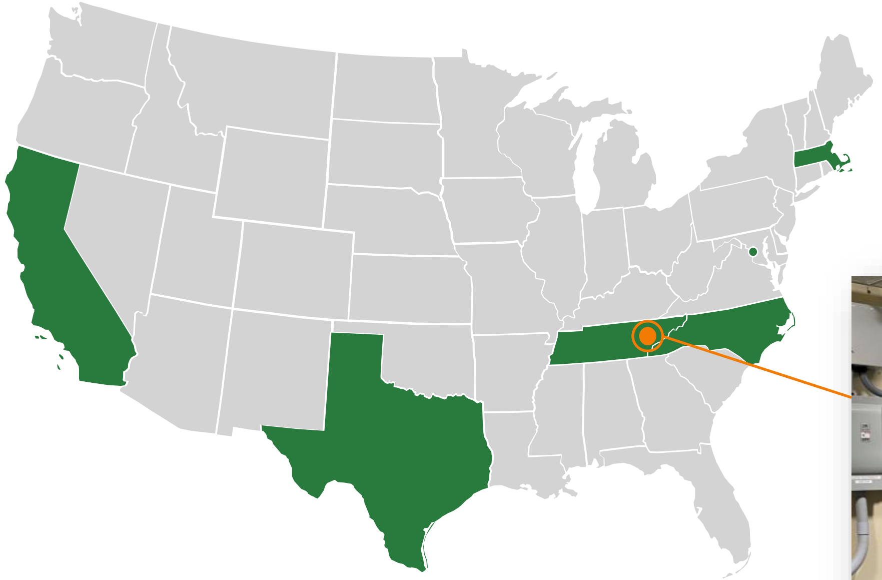
OPSLab

The **OPS Lab** can emulate a complete power distribution system from the operator to the device.

Research programs in EPRI's power delivery & utilization sector leverage a combination of real and simulated devices to perform realistic and scalable testing.

OPSLab Location and Team

EPRI Locations in the U.S.A.



OPSLab

Power Delivery and Utilization

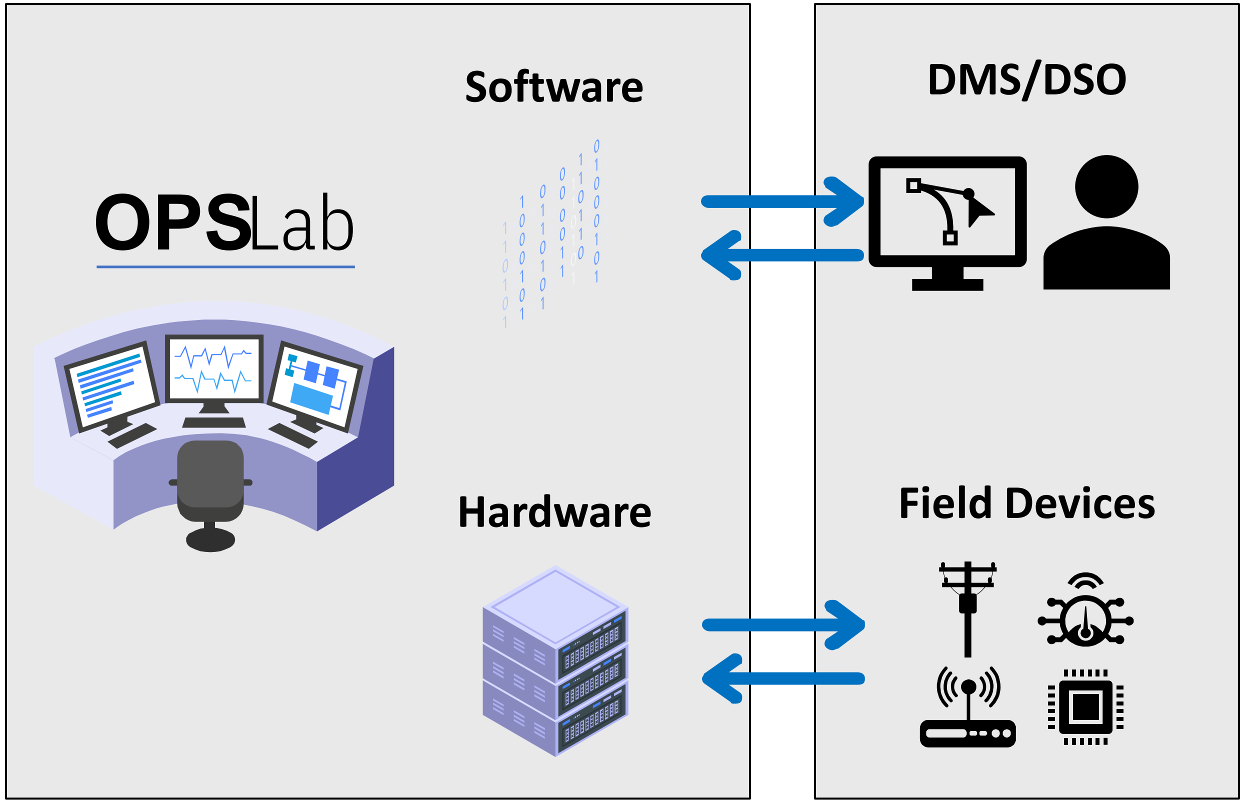
- Distribution Operations and Planning (P200)
- DER Integration (P174)
- Bulk System Integration of Renewables and Distributed Energy Resources (P173)

$\underbrace{\text{Distribution Operations and Planning (P200)} \quad \text{DER Integration (P174)}}_{\text{Distribution}} \quad \underbrace{\text{Bulk System Integration of Renewables and Distributed Energy Resources (P173)}}_{\text{Transmission}}$

EPRI operates its main offices and laboratories in the United States, along with the international office locations of EPRI, EPRI International and EPRI Europe. The **OPS Lab** is located at the EPRI offices in Knoxville, TN.

OPSLab Applications Include

- Developing and testing new control algorithms and automation schemes
- Evaluating new protection technologies, logic and approaches
- Developing tools and training for the future operator

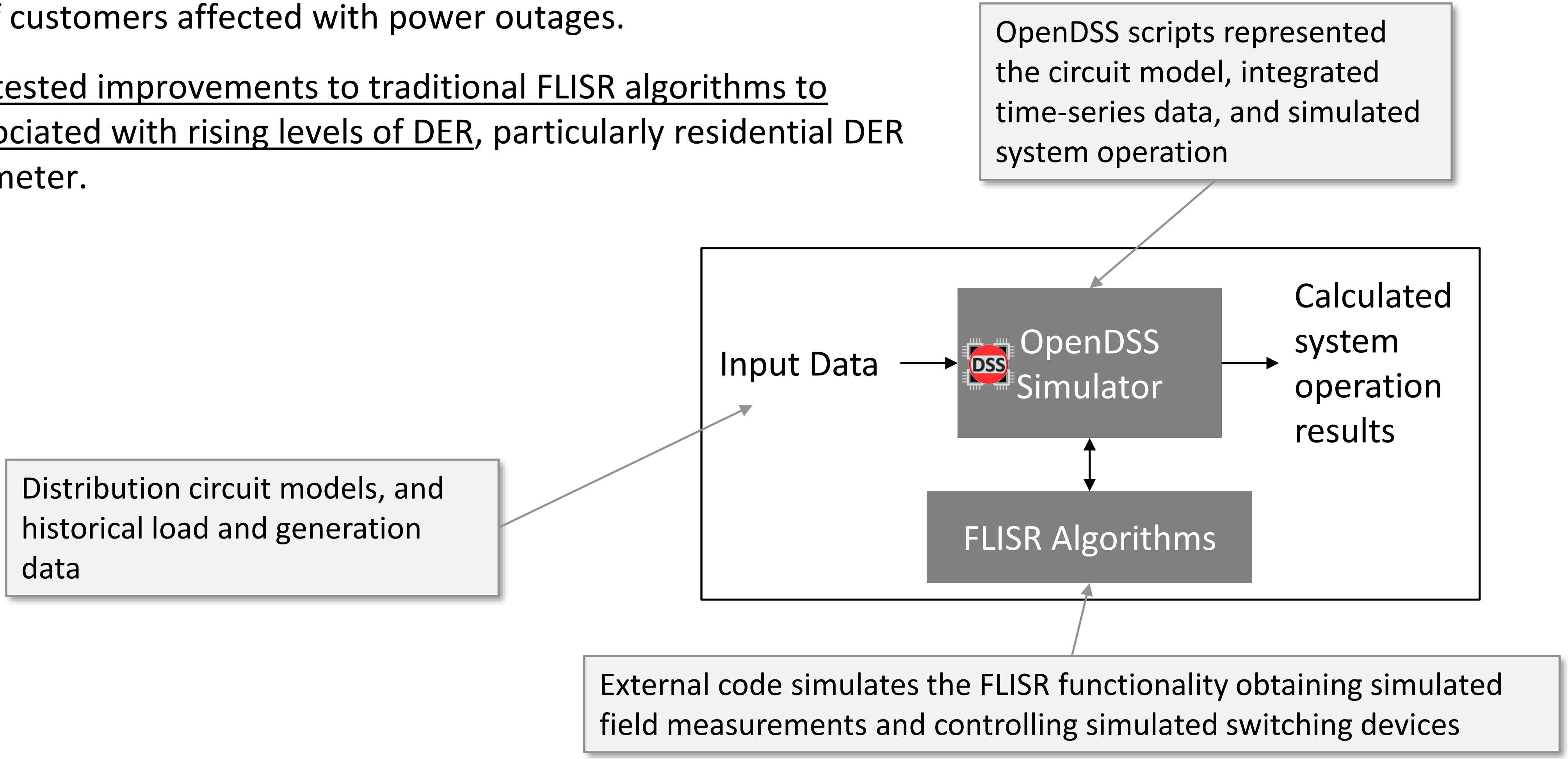


Bridging the gap between planned and field-ready deployments by allowing the deployment and prototyping of innovative solutions on **actual** and **simulated** protection, control, and automation devices.

Example: Advanced FLISR Algorithms

One of the most successful options for improving the reliability and resilience of the electric distribution system is distribution automation (DA). Fault Location Isolation and Service Restoration (FLISR) leverages DA to minimize the time and number of customers affected with power outages.

EPRI proposed and tested improvements to traditional FLISR algorithms to solve the issues associated with rising levels of DER, particularly residential DER hidden behind the meter.



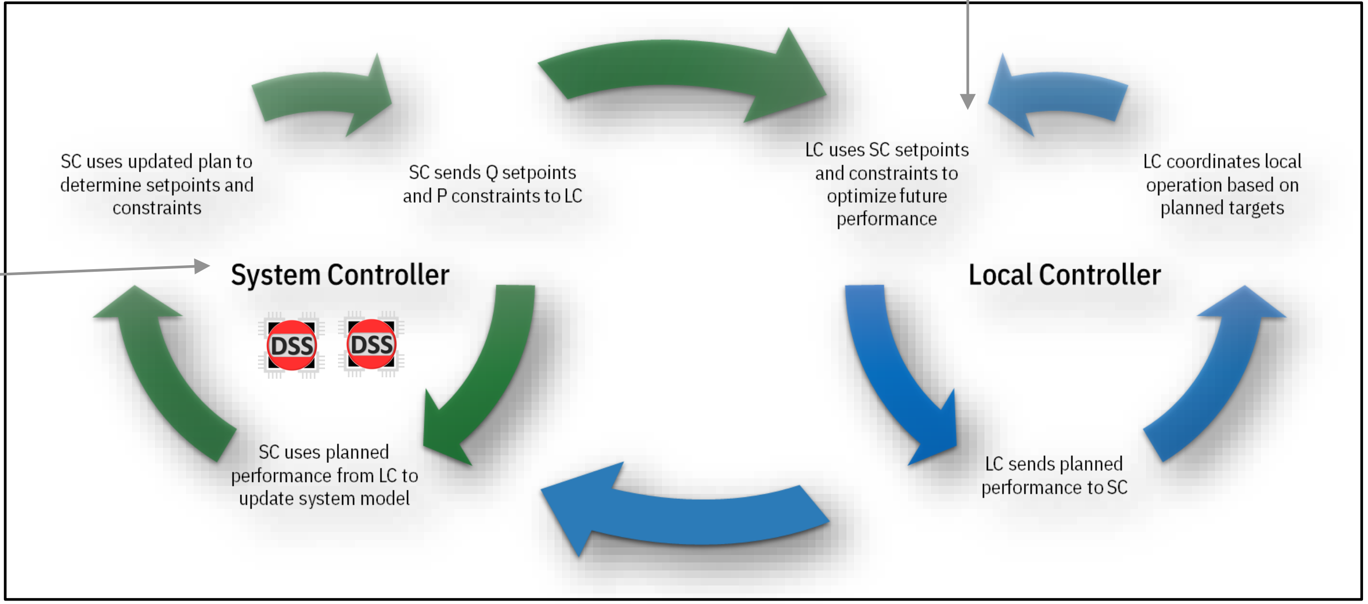
Example: SHINES Hybrid Control Field Demonstration

A hybrid solution refers to centralized and decentralized controls coordinating a technology mix. The hybrid control field demonstration connects a centralized controller located in the EPRI's **OPS Lab** to a local controller in the field through SCADA and the use of industry protocols.

EPRI designed and tested the two-level control architecture with optimization algorithms at each level (system, OPS Lab, and local controllers, field site)

Local controller in the field connected to the OPS Lab SCADA for testing hybrid control strategy

The system controller uses two instances of OpenDSS to (1) simulate actual system conditions, and (2) simulate thousands of hypothetical scenarios.



The sustainable and holistic integration of energy storage and solar PV (SHINES) project was sponsored by U.S. Department of Energy.

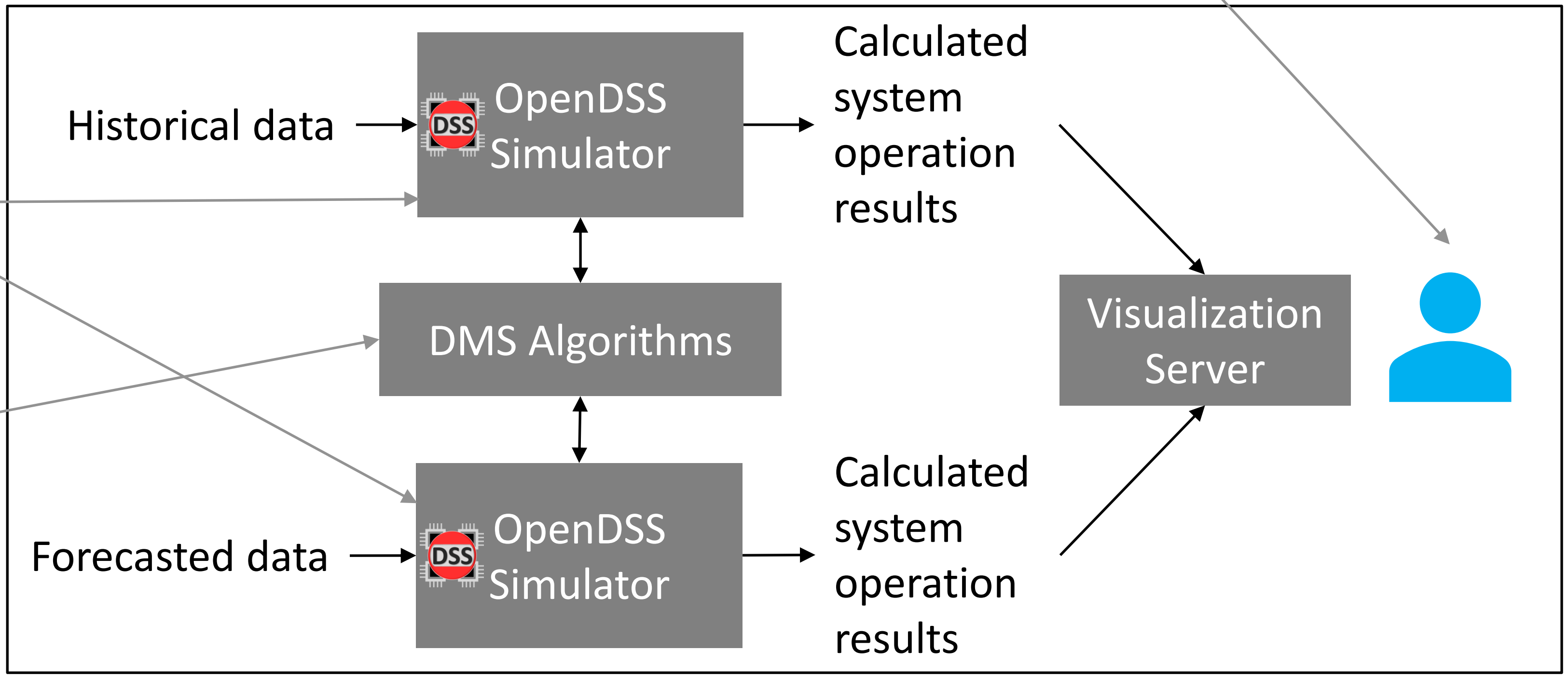
Example: Demonstration of Advanced Solar and Load Forecasting into Operational Environments

Utilities face challenges in distribution system operations because of limited visibility of DER production observed during the daily operation of systems that currently experience significant DER penetration. Those challenges have the potential to significantly impact the reliability and overall performance of the grid if they are not preventively resolved with updated operational practices and tools. Methods for integrating forecast data with operational functions were demonstrated at the **OPS Lab**.

External users can analyze data from multiple scenarios to evaluate the potential for integrating forecasts during system operation

Two instances of OpenDSS are used to simulate the system operation with alternative data inputs

External code simulates the DMS functions operating under different system conditions

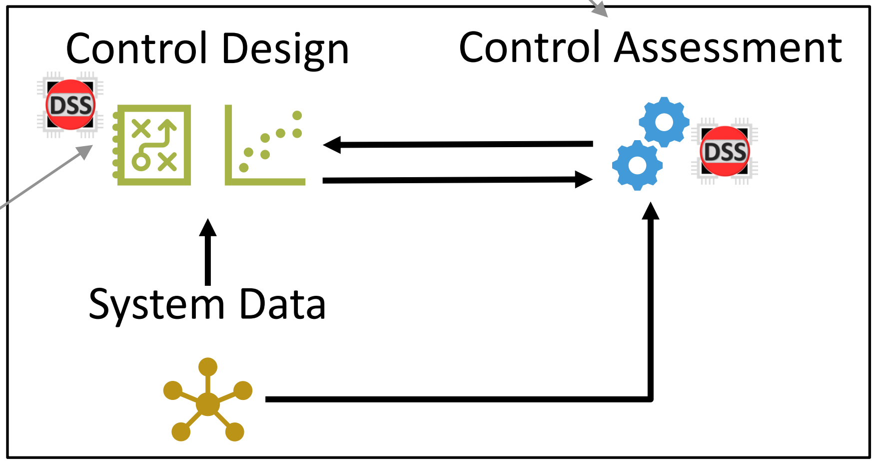


Example: Hybrid Volt-var Optimization (VVO) Solution

EPRI has proposed and evaluated a hybrid control approach for volt-var optimization for distribution systems with high penetration of DER. This control method was tested with tools from the EPRI's **OPS Lab** to achieve a real-time emulation of operations with a distribution test system.

Using planning models and data, the emulation enabled bidirectional data streams between a commercial ADMS and an emulated version of the distribution system.

OpenDSS and other co-simulation tools were used to test the performance of final implementation of control algorithms

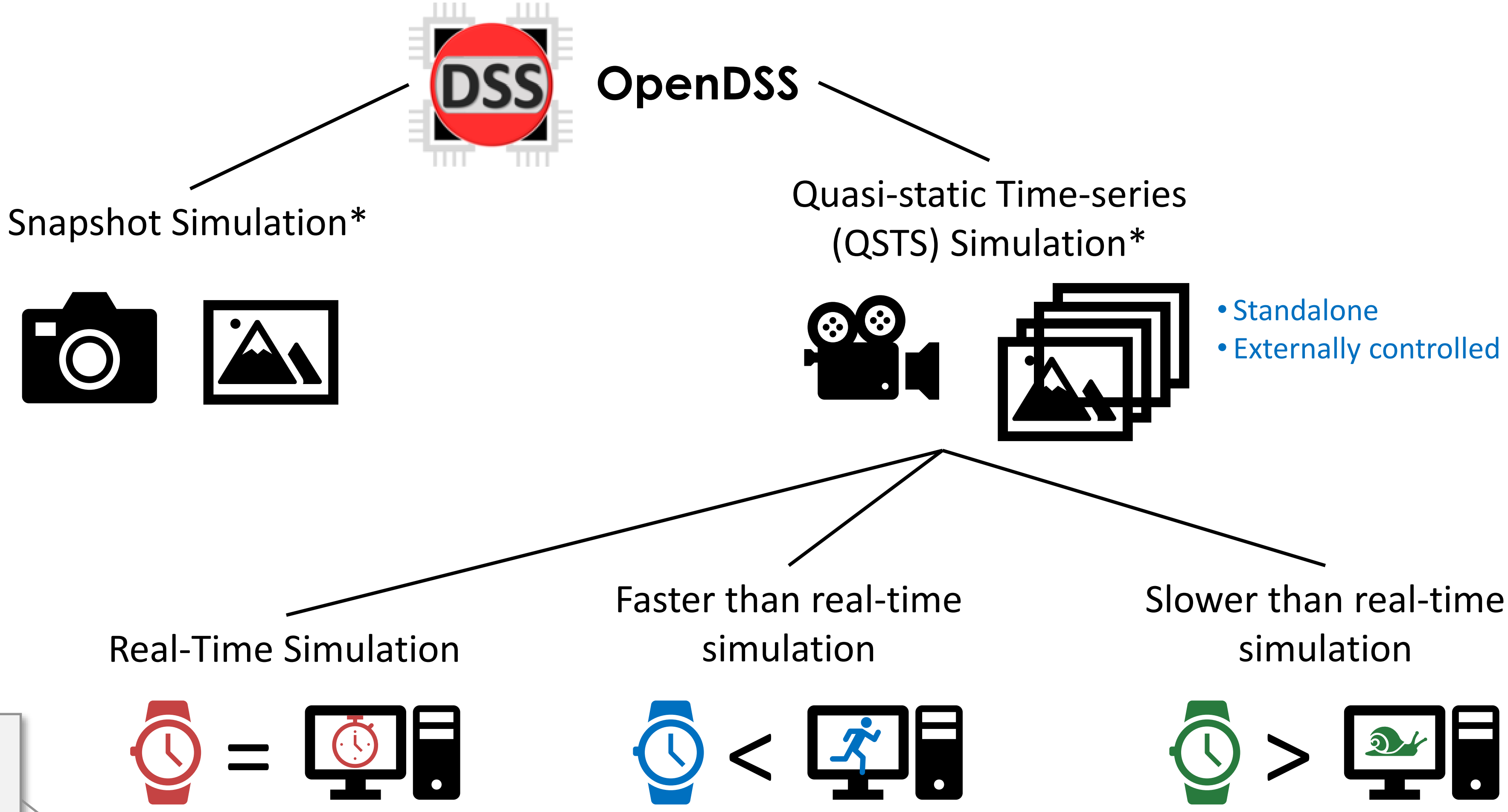


This stage included refinements to the control logic based on OpenDSS simulations and improvements to vendor tools to resolve detected operational issues

Multiple Simulation Approaches for Multiple Assessment and Validation Needs

Execution Modes

- Standalone
  - OpenDSS.exe
  - OpenDSSCmd.exe
- Externally controlled
  - OpenDSSEngine.dll
  - OpenDSSDirect.dll



Real-time applications require external control algorithms to achieve time synchronism

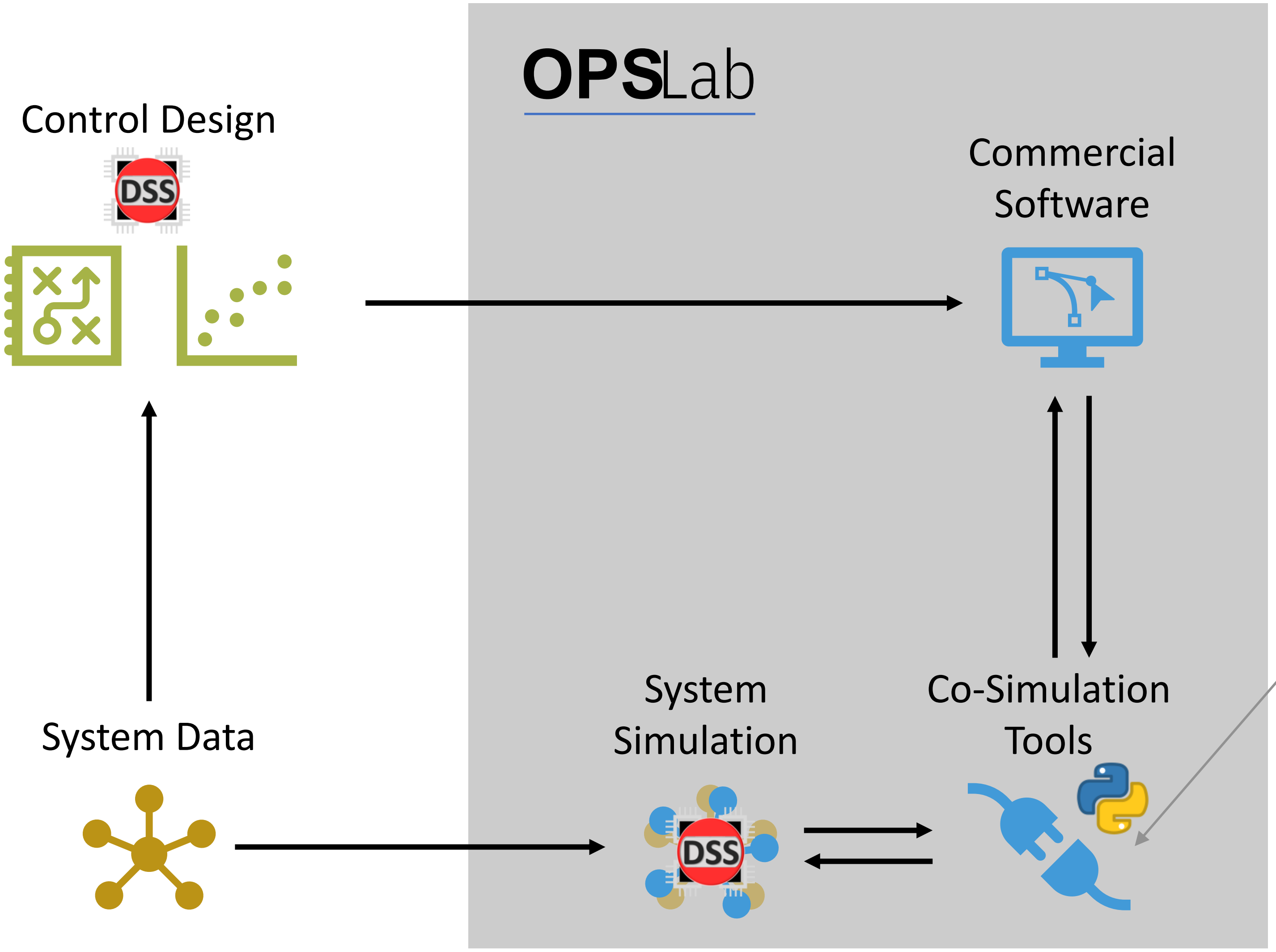
Real-Time Simulation:
- Externally controlled

Faster than real-time simulation:
- Standalone
- Externally controlled

Slower than real-time simulation:
- Standalone
- Externally controlled

* OpenDSS supports additional simulation modes such as harmonics, dynamics, fault study, Monte Carlo.

External Control for Real-Time Simulation with OpenDSS



Component synchronism and data management are critical factors to achieve real-time operation in the assessment environment. Component coordination was implemented with Python tools using a server-client architecture controlling the OpenDSS-G QSTS simulation.

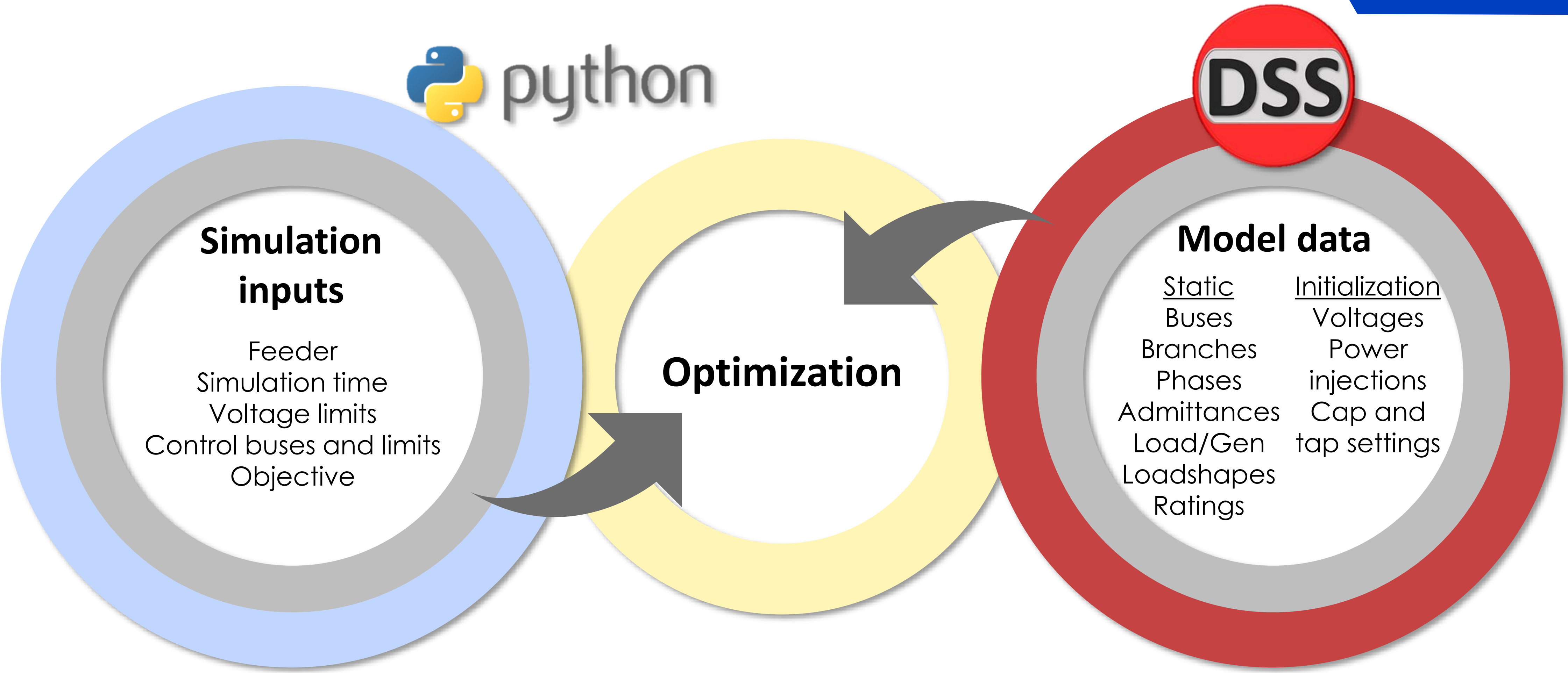
3 - Distribution Optimal Power Flow Tool

Distribution OPF

- Three-phase unbalanced optimal power flow
- Python based
- Input data from OpenDSS
- Optimization modelled with Pyomo
  - Ipopt solver for problems without integer/binary variables
  - Bonmin solver for problems with integer/binary variables
- Major distribution components modelled
  - Loads, generators, lines, transformers, regulators, capacitors, PV
- Time series simulations (looping optimization)

Finds optimal values for distribution control variables to achieve a specified objective

Inputs


python
DSS
Simulation inputs
Feeder
Simulation time
Voltage limits
Control buses and limits
Objective
Optimization
Model data
Static
Buses
Branches
Phases
Admittances
Load/Gen
Loadshapes
Ratings
Initialization
Voltages
Power injections
Cap and tap settings

DOPF Formulation

Sets
- Buses
  - Source bus
  - Primary buses
  - Capacitor buses
  - PV buses
  - New load/gen buses
- Branches
  - Regulator branch
- Phases

Parameters
- Branch admittance (G&B)
- Branch ratings
- Bus load (P&Q)
- Bus load ZIP components
- Bus generation (P&Q)
- Bus capacitor
- Bus PV (P&Q)
- Source bus ref voltage (mag & ang)

Variables

Variables
- Bus voltage (mag & ang)
- Bus power injection (P&Q)
- Branch power flow (P&Q)

Control variables
- Regulator tap position
- Capacitor status
- PV output
- New load/gen output
- …

Constraints

Equality
- Bus KCL (P&Q)
- Source bus voltage (mag & ang)

Inequality
- Voltage limits
- Current limits
- Power limits

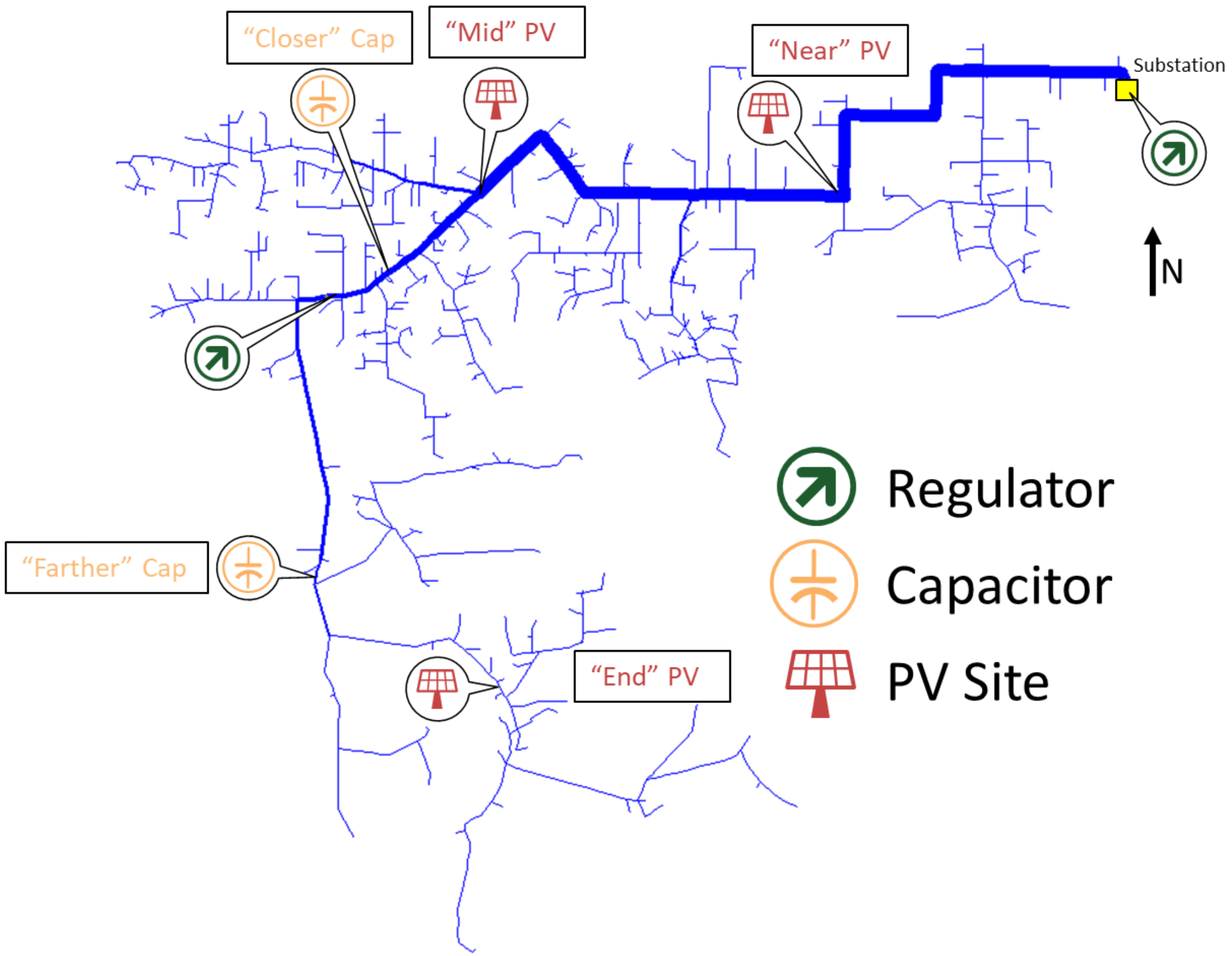
https://www.epri.com/research/products/000000003002022952

Objectives

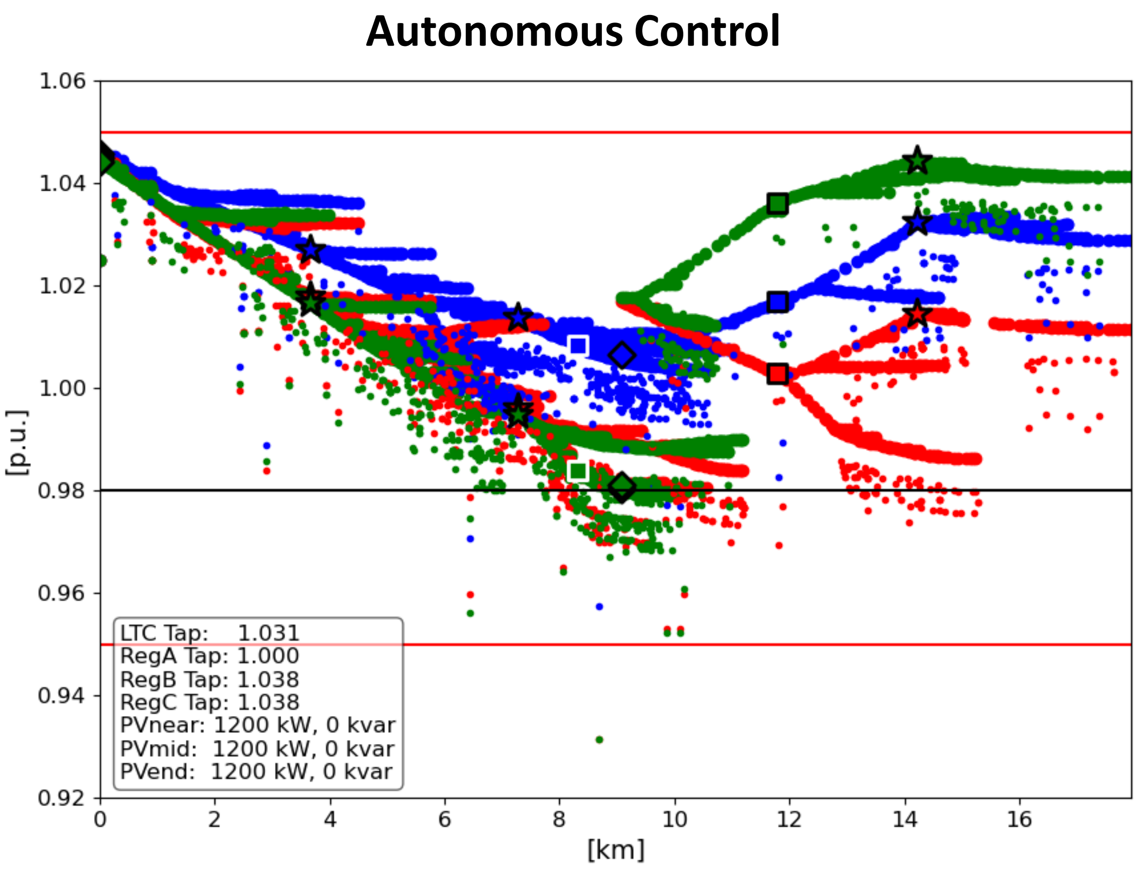
- Planning objectives
  - Maximize size of new load/generator
- Operational objectives
  - Minimize consumption
  - Minimize losses
  - Flatten voltage profile
- Flexibility to add custom objectives to suit application

Example

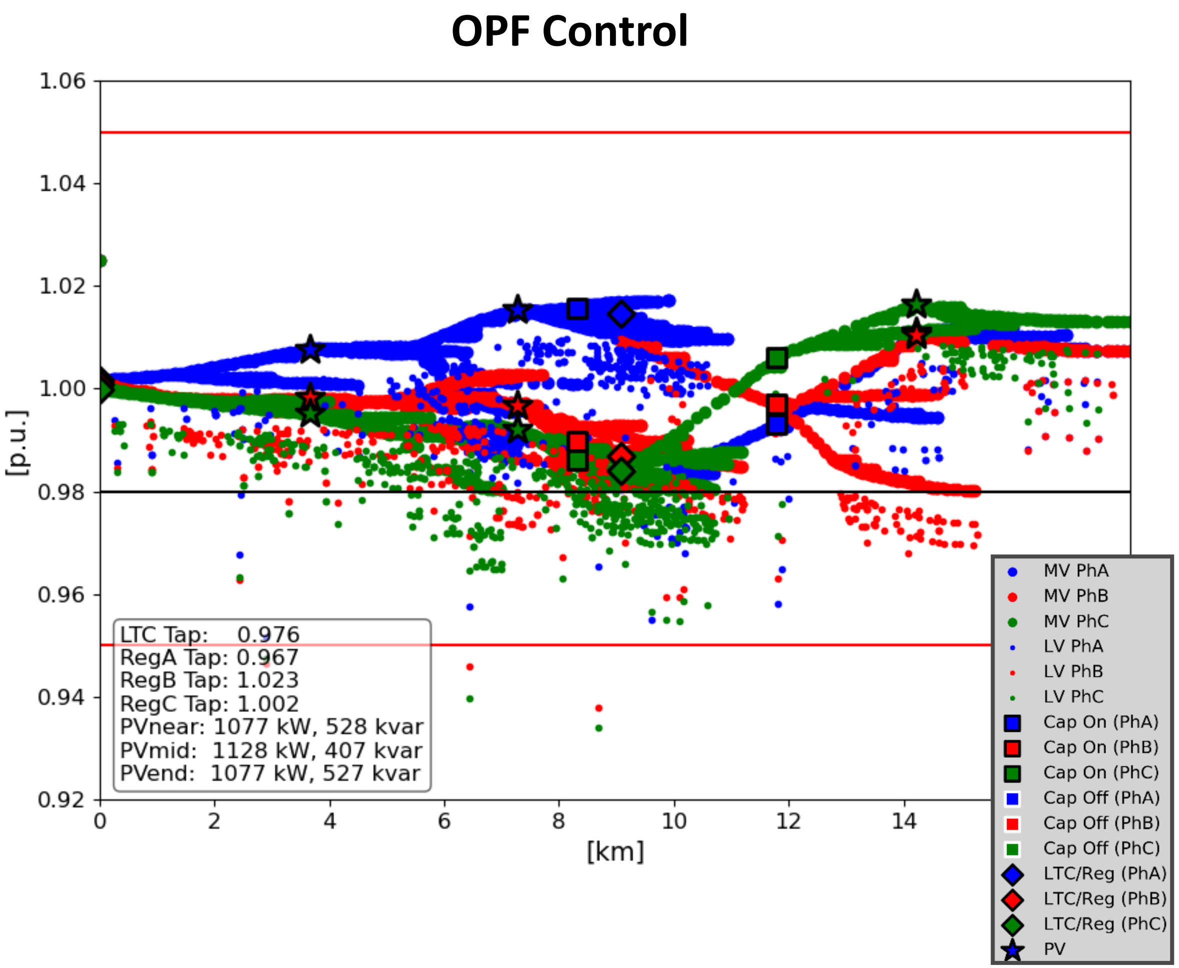
- Test feeder with multiple controllable devices
  - Regulators
  - Capacitors
  - PV
- CVR objective – lower and flatten voltage across feeder
  - Minimize all voltages
  - Constrain primary bus voltage to be above 0.98 pu



Example

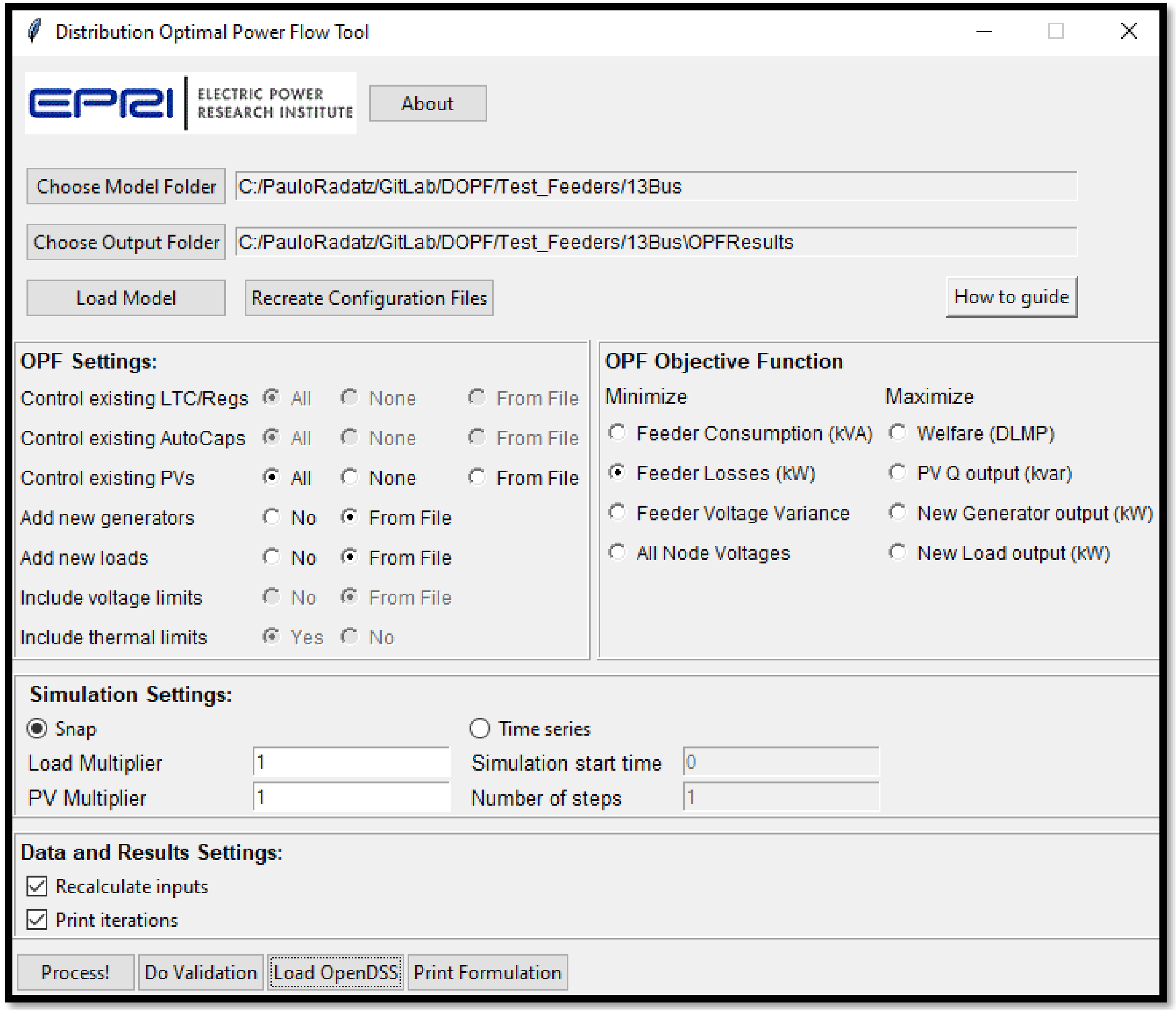


Autonomous Control
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
[p.u.]
0
2
4
6
8
10
12
14
16
[km]
LTC Tap: 1.031
RegA Tap: 1.000
RegB Tap: 1.038
RegC Tap: 1.038
PVnear: 1200 kW, 0 kvar
PVmid: 1200 kW, 0 kvar
PVend: 1200 kW, 0 kvar



OPF Control
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
[p.u.]
0
2
4
6
8
10
12
14
[km]
LTC Tap: 0.976
RegA Tap: 0.967
RegB Tap: 1.023
RegC Tap: 1.002
PVnear: 1077 kW, 528 kvar
PVmid: 1128 kW, 407 kvar
PVend: 1077 kW, 527 kvar
MV PhA
MV PhB
MV PhC
LV PhA
LV PhB
LV PhC
Cap On (PhA)
Cap On (PhB)
Cap On (PhC)
Cap Off (PhA)
Cap Off (PhB)
Cap Off (PhC)
LTC/Reg (PhA)
LTC/Reg (PhB)
LTC/Reg (PhC)
PV

Distribution Optimal Power Flow Tool



4 - Teaching Students Distribution Modeling and Analysis using OpenDSS

External Speaker

Robert Kerestes, PhD– email: rjk39@pitt.edu

Robert Kerestes, PhD, is an assistant professor of electrical and computer engineering at the University of Pittsburgh's Swanson School of Engineering. Bob was born in the Mount Washington neighborhood of Pittsburgh, Pennsylvania. He got his B.S. (2010), his M.S (2012). and his PhD (2014) from the University of Pittsburgh, all with a concentration in electric power systems. His areas of interest are in modelling and analysis of electric power distribution systems, smart grid technology, and the integration of distributed energy resources & electric vehicles. He is the coauthor, along with Bill Kersting, of the Fifth Edition of Distribution System Modeling and Analysis with MATLAB and WindMil. Prior to academia, Bob worked as a mathematical modeler for Emerson Process Management, working on electric power applications for Emerson's Ovation Embedded Simulator. Bob also served in the United States Navy as an interior communications electrician from 1998-2002 on active duty and from 2002-2006 in the US Naval Reserves.

Teaching Students Distribution Modeling and Analysis using OpenDSS

Dr. Robert Kerestes
University of Pittsburgh
Swanson School of Engineering
Department of Electrical and Computer Engineering

Courses:

- ECE 1710 (UG) – Power Distribution Engineering and Smart Grid
- ECE 2795 (G) – Distribution System Modeling and Analysis

ECE 1710 – Power Distribution Engineering and Smart Grid

Upon completion of the course, students can:

- Develop mathematical models of of distribution systems equipment including transmission lines, transformers, capacitors, loads…etc.
- Write computer programs using MATLAB which produce the equivalent impedance and admittance models for the equipment
- Write computer programs using MATLAB which perform linear circuit analysis and iterative nonlinear circuit analysis for distribution circuits
- Use both OpenDSS and Milsoft WindMil giving them exposure to both open source and commercial simulators used in the distribution space
- Use both OpenDSS and Milsoft WindMil to validate mathematical models and circuit solutions
- Use both OpenDSS and Milsoft WindMil to solve power quality issues in a small radial distribution circuit

Assessment Example 1:

Problem Summary

Design a MATLAB function called overheadLine. This simulation algorithm calculate the impedance matrix for a three phase overhead transmission line with a neutral connection. You will pass this algorithm two structs, one for the phase conductors and one for the neutral conductors. The first struct should be named “phase_cond” and will have fields:

- phase.resistance – this will be the resistance of the phase conductors in Ω/mi
- phase.diameter – this will be the diameter of the phase conductors in inches
- phase.GMR – this will be the geometric mean radius of the phase conductors in feet
- phase.x_a – the location of the a conductor’s x coordinate in feet
- phase.y_a – the location of the a conductor’s y coordinate in feet
- phase..x_b – the location of the b conductor’s x coordinate in feet
- phase.y_b – the location of the b conductor’s y coordinate in feet
- phase.x_c – the location of the c conductor’s x coordinate in feet
- phase.y_c – the location of the c conductor’s y coordinate in feet

The second struct should be named “neutral_cond” and will have fields:

- neutral.resistance – this will be the resistance of the neutral conductor in Ω/mi
- neutral.diameter – this will be the diameter of the neutral conductor in inches
- neutral.GMR – this will be the geometric mean radius of the neutral conductor in feet
- neutral.x_n – the location of the neutral conductor’s x coordinate in feet
- neutral.y_n – the location of the neutral conductor’s y coordinate in feet

In addition, the function should be passed optional parameters which will

- f – system frequency

Your function should check if frequency and/or resistivity was passed. If these functions were not passed, then the shoudl be set to their default values of 60 Hz for frequency and 100 ohm-m for resistivity.

In addition, you will need to pass an additional array called config. This determines which lines are connected. For an overhead line, config will have four elements and will be a row vector. The elements will be binary and will indicate the presence of a phase conductor or neutral. So fro example, a two phase line with phases a and c and one neutral would have

$$\text{config} = \begin{bmatrix} 1 \\ 0 \\ 1 \\ 1 \end{bmatrix}$$

When this function is called it should output the primitive impedance matrix, where each element gives the impedance in Ω/mi:

$$[\hat{z}_{primitive}] = \begin{bmatrix} \hat{z}_{aa} & \hat{z}_{ab} & \hat{z}_{ac} & \hat{z}_{an} \\ \hat{z}_{ba} & \hat{z}_{bb} & \hat{z}_{bc} & \hat{z}_{bn} \\ \hat{z}_{ca} & \hat{z}_{cb} & \hat{z}_{cc} & \hat{z}_{cn} \\ \hat{z}_{na} & \hat{z}_{nb} & \hat{z}_{nc} & \hat{z}_{nn} \end{bmatrix}$$

Note that once you complete this assignment, you can use it for your homework.

Students enter code here

Function

```
function zprim = overheadLine(phase,neutral,config,f,rho)

end

```

Call function with this code

Code to call your function

```
%Defining the phase conductor data
phase.GMR = 0.0244;
phase.resistance = 0.306;
phase.x_a = 0;
phase.y_a = 29;
phase.x_b = 2.5;
phase.y_b = 29;
phase.x_c = 7;
phase.y_c = 29;


%Defining the neutral conductor data
neutral.GMR = 0.00814;
neutral.resistance = 0.592;
neutral.x_n = 4;
neutral.y_n = 25;

%Defining the configuration
config = [1;1;1;1];

f = 60;
rho = 100;

zprim = overheadLine(phase,neutral,config,f,rho)
```

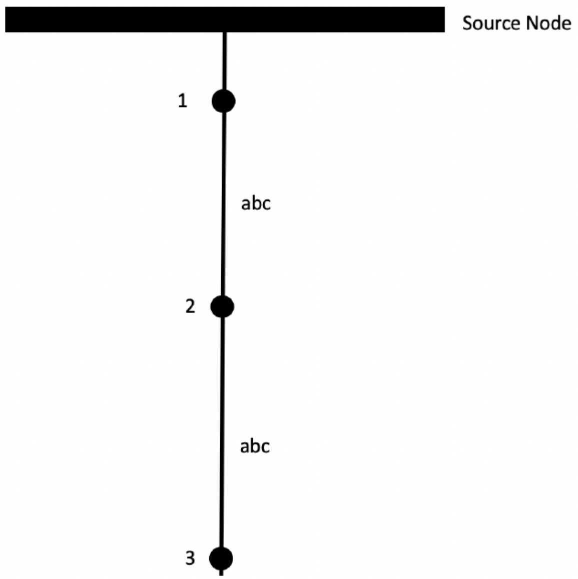
Assessment Example 2:

- Using OpenDSS and WindMil to validate T-Line Modeling

Project Simulator Validation

We will use two simulators to validate our results. First, we will use the commercial simulator Milsoft WindMil which is used for many energy cooperatives in rural areas. Secondly, we will use the Open Source EPRI tool, OpenDSS. OpenDSS is commonly used for research at National Laboratories and at universities.

Create a model both in WindMil and OpenDSS which defines the source node shown below which is a 12.47 kV, Y connected source



The three-phase OH lines

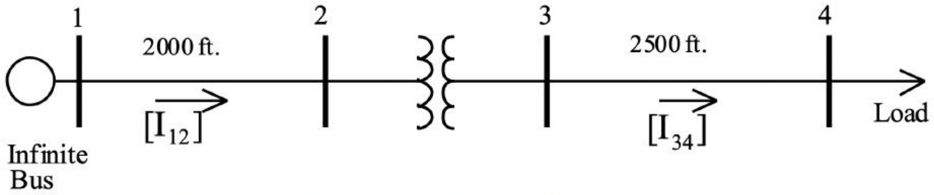
a. Phase: 336,400 26/7 ACSR
b. Neutral: 4/0 6/1 ACSR
c. Phasing: *a–b–c*
d. Spacings:
   Phase a: x = -4, y = 29
   Phase b: x = -1.5, y = 29
   Phase c: x = 3, y = 29
   Neutral: x = 0, y = 25
e. OH 0: Nodes 1-2, 100 ft.
f. OH 1: Nodes 2–3, 2500 ft.

Final Assessment

Simulator Project Report:

The project report should contain the following

1. Introduction – In this section explain what your simulator does. Your simulator should simulate single line systems with no lateral branches. For example the IEEE 4-Bus Test System (shown below)



2. Documentation – In order to solve a single line system, you need to use the following models
    a. Voltage source
    b. Transmission line
    c. Transformer (delta-grounded wye, or single-phase)
    d. Load

   These models need to be documented as instructed in the project assignments
3. Test case and results – A verification of your simulator with the IEEE Test System. In this section simulate the IEEE 4-Bus Test system with a delta-grounded wye transformer. Explain any discrepancies between the two (for example, you can use the modified forward sweep-backward sweep, but explain how the results are different due to this)
4. Validate this system using OpenDSS and WinMil and show the results of these programs vs. your simulator
5. Reference section – reference the material used to develop your simulator and the associated document

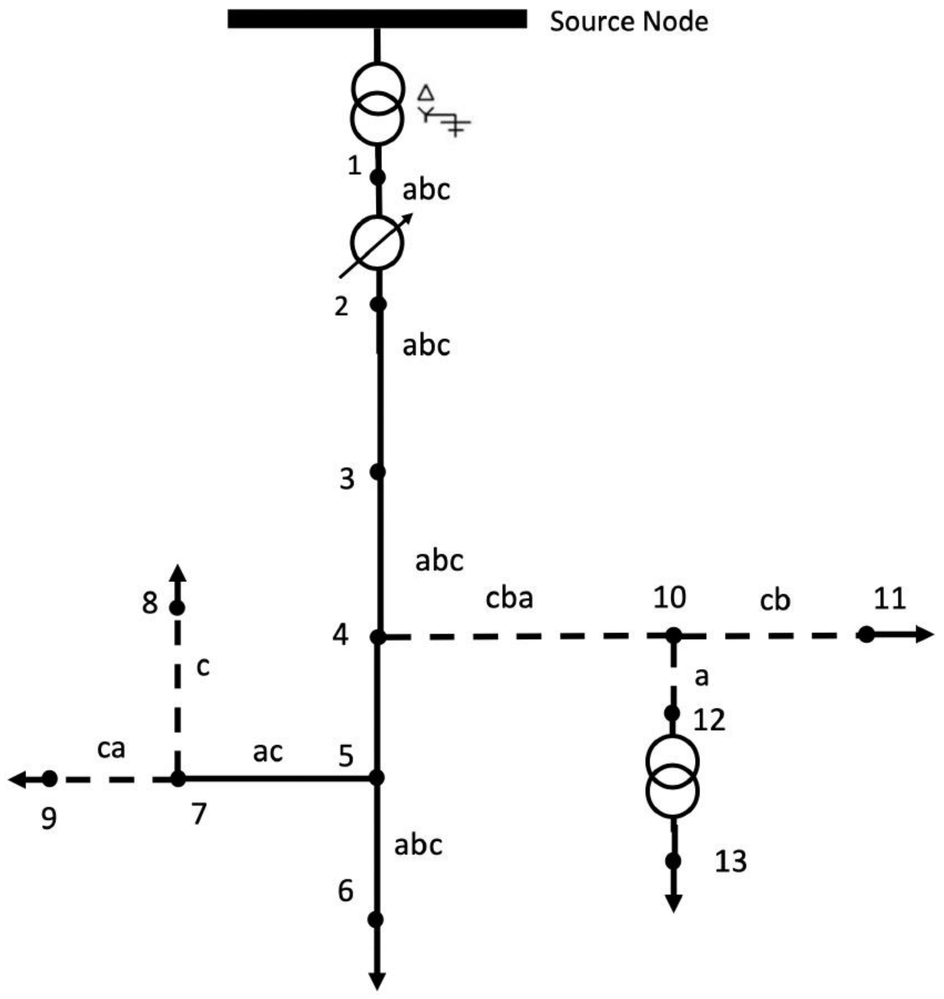
Note: Make this as professional looking as possible. Imagine you and your team had a startup and this simulator is your main product. What would you like to present to potential investors and customers?

MATLAB Source Code

Please submit a zip file the main script to solve the IEEE Test System and all the functions called to solve this. The IEEE Test system should run.

New 13 Node Circuit Model

- Model entire circuit from scratch using OpenDSS
- Determine regulator compensator circuit parameters to achieve desired voltage at load center
- Experiment with capacitor placement to improve voltage and reduce losses



Contact Email

rjk39@pitt.edu

External Speakers (Students)

- **Raju Wagle – email: raju.wagle@uit.no**

Raju Wagle received his Bachelor's degree in Electrical Engineering (2009) from Institute of Engineering (IOE), Pulchowk Campus, Nepal, and a Master's degree in Electrical Engineering (2015) from Narvik University College, Norway. Currently, he is pursuing his PhD at the Department of Electrical Engineering, Faculty of Engineering Science and Technology, UiT The Arctic University of Norway, Campus Narvik, Norway. Before his PhD, he was working as a Lecturer at the Department of Electrical and Electronics Engineering, Pokhara University, Nepal. His research interests include grid integration of renewable energy sources, cyber-physical co-simulation, real-time optimal control and so on.

- **Lucas Rodrigues de Almeida – email: ralmeida.lucas@gmail.com**

Lucas Rodrigues de Almeida is an Electrical Engineering Professor at Federal Institute of Triângulo Mineiro and a Ph.D student at Federal University of Uberlândia, Brazil. His current research activities focus on modeling and analysis of distribution systems, photovoltaic distributed generation and power quality. He received the BSEE (2011) degree from University of Uberaba and the Master (2016) degree in Electrical Engineering from the Federal University of Uberlândia. He has experience with OpenDSS since 2019.

- **Sushrut Thakar – email: sushrut.thakar@asu.edu**

Sushrut Thakar is currently a graduate student at School of Electrical, Computer and Energy Engineering, Arizona State University, USA, where he is working towards his PhD degree. Before joining Arizona State University, he received the M.Tech. degree in energy systems engineering from the Indian Institute of Technology Bombay, India, in 2018. In addition to his research at Arizona State University, he was a student intern at EPRI during Fall 2021. His research interests include distribution system modeling, transmission & distribution co-simulation and grid integration of renewable resources.

5 - Application of OpenDSS in Optimal Real-Time Reactive Power Control using Smart Inverter in Distribution Network

Application of OpenDSS in Optimal Real-Time Reactive Power Control using Smart Inverter in Distribution Network

Why ??

- To cope with the uncertainties due to high penetration of distributed energy resources.
- The proposed system can be implemented on any kind of distribution network.

How??

- European CIGRE MV Benchmark distribution network with DERs is modelled in OpenDSS.
- OpenDSS is simulated in Typhoon HIL using Python
- The co-simulation based optimization is implemented in Python inside Typhoon HIL.
- The monitoring system designed in Typhoon HIL activate the optimization block to obtain the new set of reactive power reference for the controller designed in Typhoon HIL real-time simulator.
- The active and reactive power obtained from the Converter is fed back to the DERs in OpenDSS.

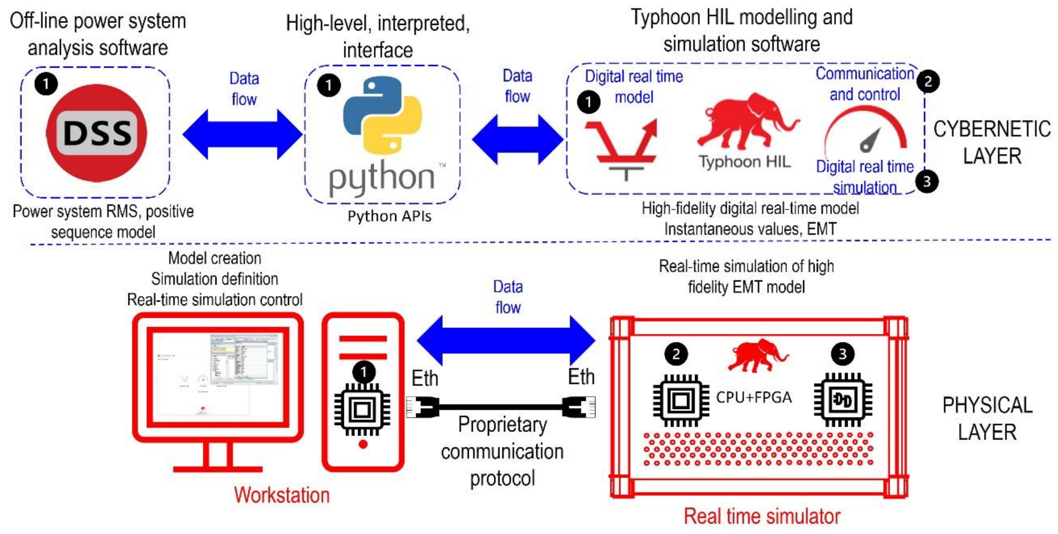


Fig. 1 Framework for cyber-physical co-simulation framework using OpenDSS and the Typhoon HIL real-time modelling and simulation framework [1]

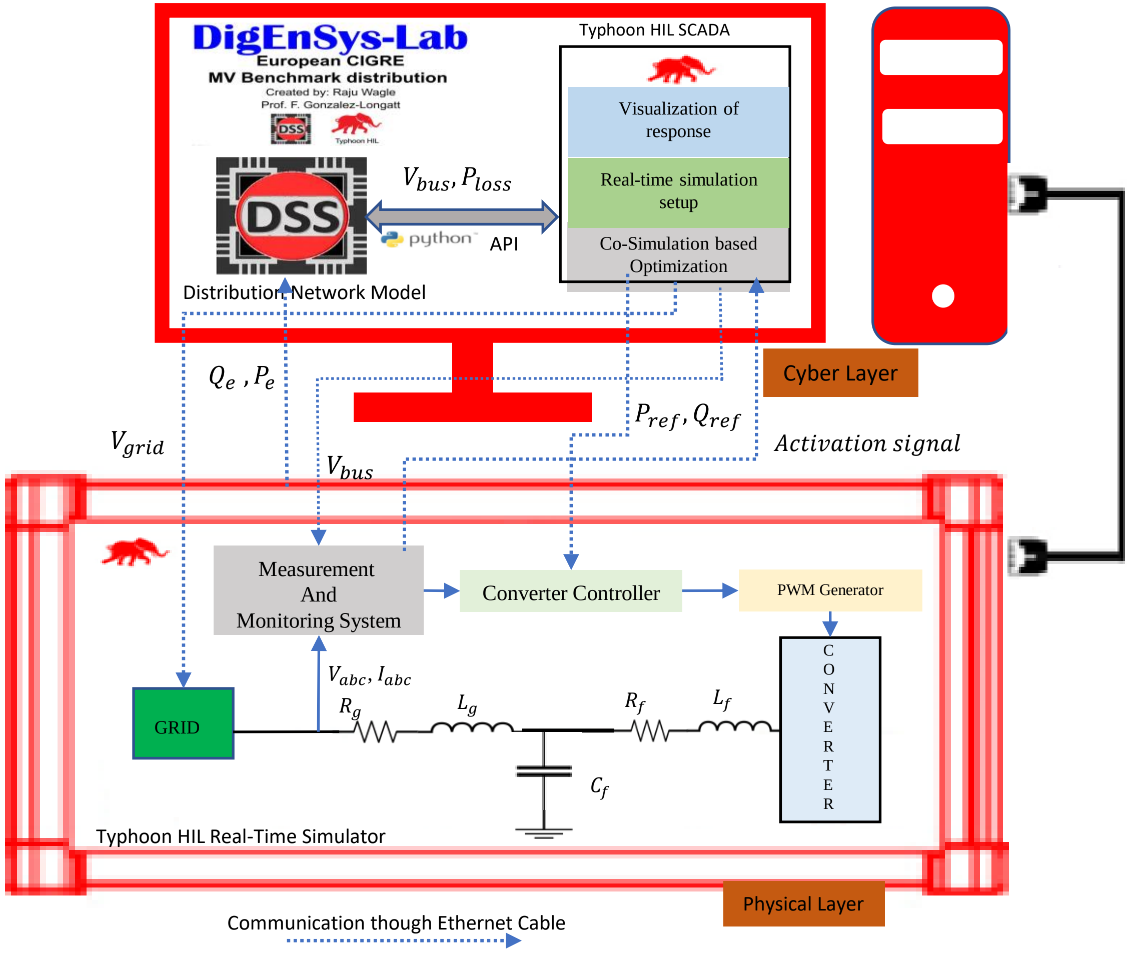


Fig. 2 Optimal real-time reactive power control using smart inverter in distribution network [2]

Presented at: OpenDSS virtual training organized by Electric Power Research Institute (EPRI)

Prepared By: Mr. Raju Wagle, Prof. F. Gonzalez-Longatt
Department of Electrical Engineering, UiT The Arctic University of Norway, Narvik, Norway
Centre for Smart Grids, University of Exeter, Exeter, United Kingdom

References:

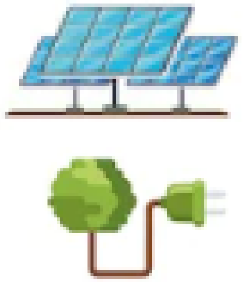
1. R. Wagle, P. Sharma, M. Amin, and F. Gonzalez-Longatt, *Cyber-physical Co-simulation framework between Typhoon HIL and OpenDSS for Real-time application, Springer Singapore*, 2022 (to be published).
2. R. Wagle, G. Tricarico, P. Sharma, C. Sharma, J. L. Reuda, and F. Gonzalez-Longatt, "*Cyber-Physical Co-Simulation Testbed for Real-Time Reactive Power Control in Smart Distribution Network*," *IEEE ISGT Asia (accepted Paper)*, 2022.

6 - The impact of photovoltaic (PV) distributed generation on power quality of distribution network and Quantification of harmonic losses in distribution systems

Distribution Systems Laboratory (LADEE) of the Federal University of Uberlândia (UFU)

R&D – ANEEL / UFU / Light (2021 – 2022)

“The impact of photovoltaic (PV) distributed generation on power quality of distribution network”



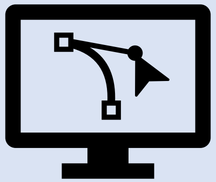
- PV inverters’ Harmonic emissivity
- Modeling both Distribution System and PV inverters on OpenDSS
- Compute Brazilian Power Quality indices

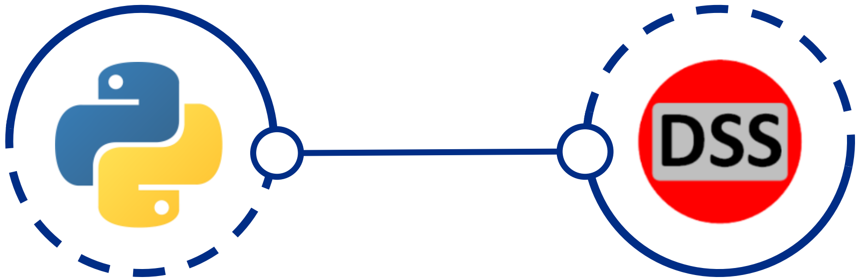
R&D – ANEEL / UFU / Equatorial (2021 – 2022)

“Quantification of harmonic losses in distribution systems”

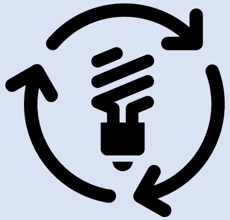
- Power Quality Measurements (800+ consumers) - residential, commercial and industrial
- Daily Loadshapes (P and Q) and Spectrums (2^{nd} to 25^{th} harmonic order)
- Skin Effect consideration

Software developed “Distributed Generation Quality Analyzer”





Power Losses Considering Real Case Scenario (500+ feeders)



7 - Real-time integrated T&D for situational awareness

Real-time integrated T&D for situational awareness

Sushrut Thakar, Arizona State University

DER 1

DER 2

. . .

DER n

Edge Device

AMI data with Q estimate; Sub-transmission source voltage/power

Edit circuit input data

T&D co-simulation power flow

Export reports

Sub-transmission model - InterPSS

Java

HELICS

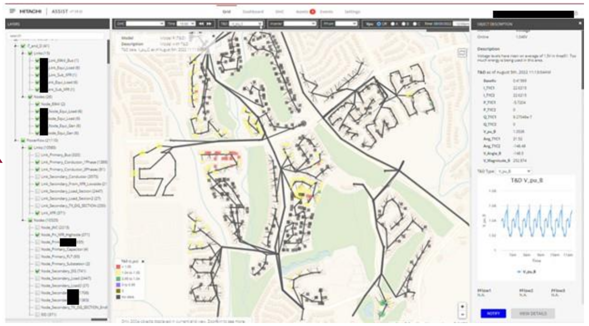
Distribution model

DSS

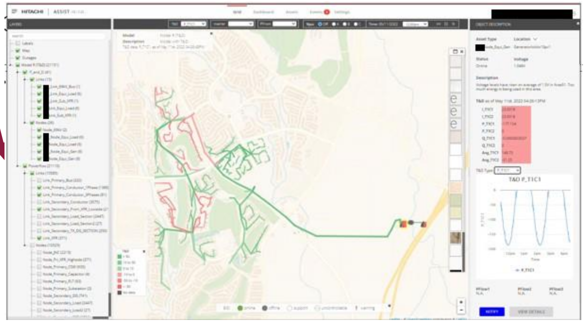
One Feeder:
Primary+secondary
7800 buses, 766 solar PV units
(>200% penetration)
4 aggregated feeders

Cloud based integrated T&D module – run every 1 minute

Other analysis modules: DHC, DER coordinated control



Voltage violations



Reverse active power flow

This slide is based on a project funded by US DOE SETO Award DE-EE0008773

Summary

It is your turn!

1. What is your field of work?

2. Where are you located?

3. Have you ever used OpenDSS?

4. If you use or have used OpenDSS, tell us for what purpose:

5. Which programming language do you use to control OpenDSS?

6. What additional topics would you like us to cover in future training?

7. What additional feature would you like to see in OpenDSS?

8. Do you have any general feedback for this webcast?

Have you missed the training and still want to answer those questions?

No worries, you can send the answer to Paulo Radatz at pradatz@epri.com

2022 OpenDSS training team

Roger Dugan

Celso Rocha

Lindsey Rogers

Andres Ovalle

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Matthew Rylander

Davis Montenegro

Miguel Hernandez

Arin Nichols


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