

# OpenDSS Training Workshop

## Advanced Topics

Jeremiah Deboever, Andres Ovalle  
EPRI Knoxville, TN

August 27, 2020



The screenshot shows a Cisco Webex Meetings interface. At the top, it says "Cisco Webex Meetings". In the center, there's a logo for "EPRI | ELECTRIC POWER RESEARCH INSTITUTE" with a background image of a globe and power infrastructure. On the left, the text "OpenDSS Virtual Training" is displayed. Below that, "EPRI Grid Operations & Planning" and "August 2020" are shown. At the bottom, there's a toolbar with various icons, and a red arrow points to the microphone icon, which is highlighted in red. A gray box with white text "Polling, Q&A" is overlaid on the bottom right. A red box with white text "Red Means Muted" is overlaid on the bottom left. A vertical arrow points upwards from the "Polling, Q&A" box towards the "EPRI" logo.

OpenDSS Virtual Training

EPRI Grid Operations & Planning  
August 2020

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Red Means Muted

Polling,  
Q&A

## Meeting Logistics

### ▪ Audio Options:

1. Connect via computer audio
2. Call local dial number and use participant code

### ▪ You are Muted on Entry

- Use Q&A to ask panelist questions

### ▪ Q&A window

- Panelist will either answer in the Q&A, or
- Panelist will voice the question

### ▪ We are Recording

### ▪ Polling window

- Polling questions will be active throughout

# OpenDSS Virtual Training 2020



Date	Time (NY time)	Session Topic
August 24	11:30 am – 12:00 pm	Distribution System Basics
	12:00 pm – 12:30 pm	Intro to OpenDSS
	12:30 pm – 1:00 pm	OpenDSS Basics and Scripting
August 25	11:30 am – 12:00 pm	Intro to OpenDSS-G
	12:00 pm – 12:30 pm	APIs, COM interface, etc.
August 26	11:30 am – 12:30 pm	PVSystem, InvControl, Storage, Storagecontroller
August 27	11:30 am – 12:30 pm	Advanced Topics
	12:30 pm – 1:00 pm	Applying OpenDSS in R&D

# Instructors

## ▪ Jeremiah Deboever, PhD

Jeremiah is a Research/Scientist II with EPRI in Palo Alto, California USA. He holds a PhD in Electrical Engineering from Georgia Institute of Technology, Atlanta GA, a MS in Renewable Energy Engineering from Oregon Institute of Technology, Wilsonville OR, and a BS in Mechanical Engineering from Binghamton University, Binghamton NY. Jeremiah has worked on different projects around distribution system modeling and simulation with a focus on DER integration studies, hosting capacity analysis, DERMS modeling, distribution load modeling, and quasi-static time-series simulation. He has published over 20 publications on electric distribution modeling/simulation and won a best poster award at the World Conference on Photovoltaic Energy Conversion in 2018.



## ▪ Andres Ovalle, PhD



Andres Ovalle is an Engineer/Scientist II in the Power System Studies team at the Electric Power Research Institute (EPRI). His current research activities focus on modeling of power systems, system protection in distribution and transmission, and impacts geomagnetic disturbance related harmonics on power systems. Mr. Ovalle joined EPRI in 2018. Prior to joining EPRI, Mr. Ovalle was with the French National Railways Company (SNCF) and the Grenoble Electrical Engineering Laboratory (G2E-lab) for approximately 2 years where he worked as a postdoctoral research engineer in the use of energy storage for the support of electrified railways. Mr. Ovalle received the B.S.E.E. degree from the Universidad de Los Andes, Bogota, Colombia, in 2011, the M.E.E. degree from the Universidad de Los Andes in 2013, and the Ph.D. in Electrical Engineering from the Université de Grenoble Alpes, Grenoble, France, in 2016.

# Advanced Topics

# Outline for today's session

- Advanced topics:

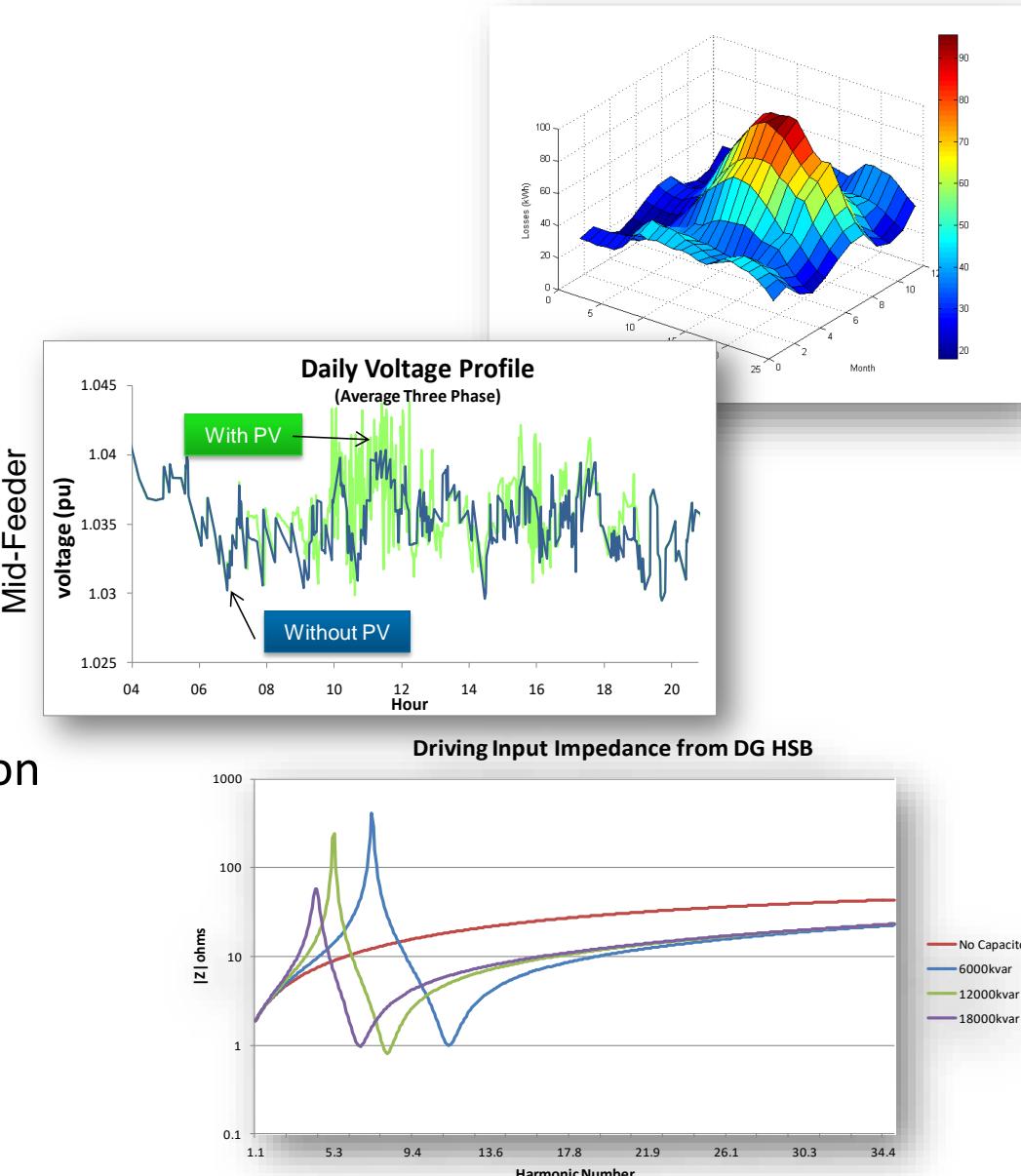
- Quasi-Static Time-Series (QSTS) simulation
- OpenDSS parallel processing capabilities
- Recloser placement
- GIC related harmonic capabilities (GICharm)

- OpenDSS in R&D:

- Available tools
- Available models and datasets
- DER integration studies
- Hosting capacity analysis
- Other examples of OpenDSS

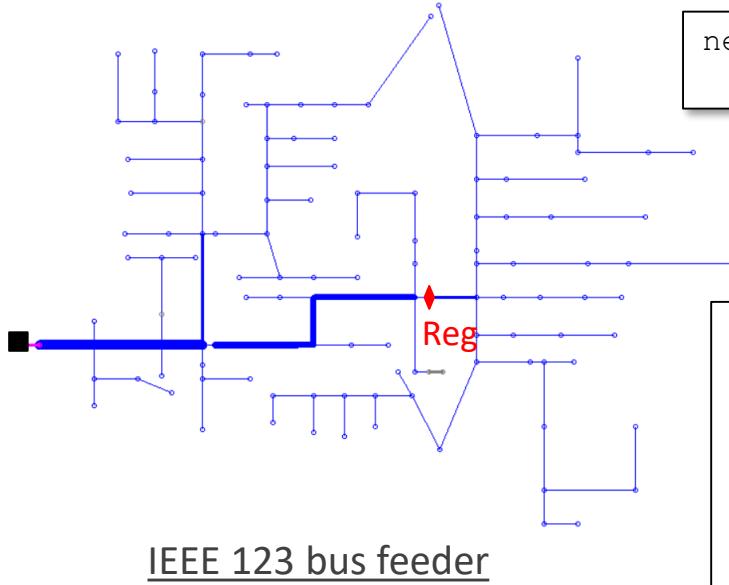
# Flexible Tool Enabling a Wide Range of Analysis Types

- DER Interconnection studies
- Locational value studies
- Hosting capacity studies
- DA/FLISR scheme evaluation
- VVO (w/ DER)
- Energy impact analysis
- DER protection impacts
- Power quality (harmonics/flicker)
- Long-range planning studies
- Smart inverter control optimization

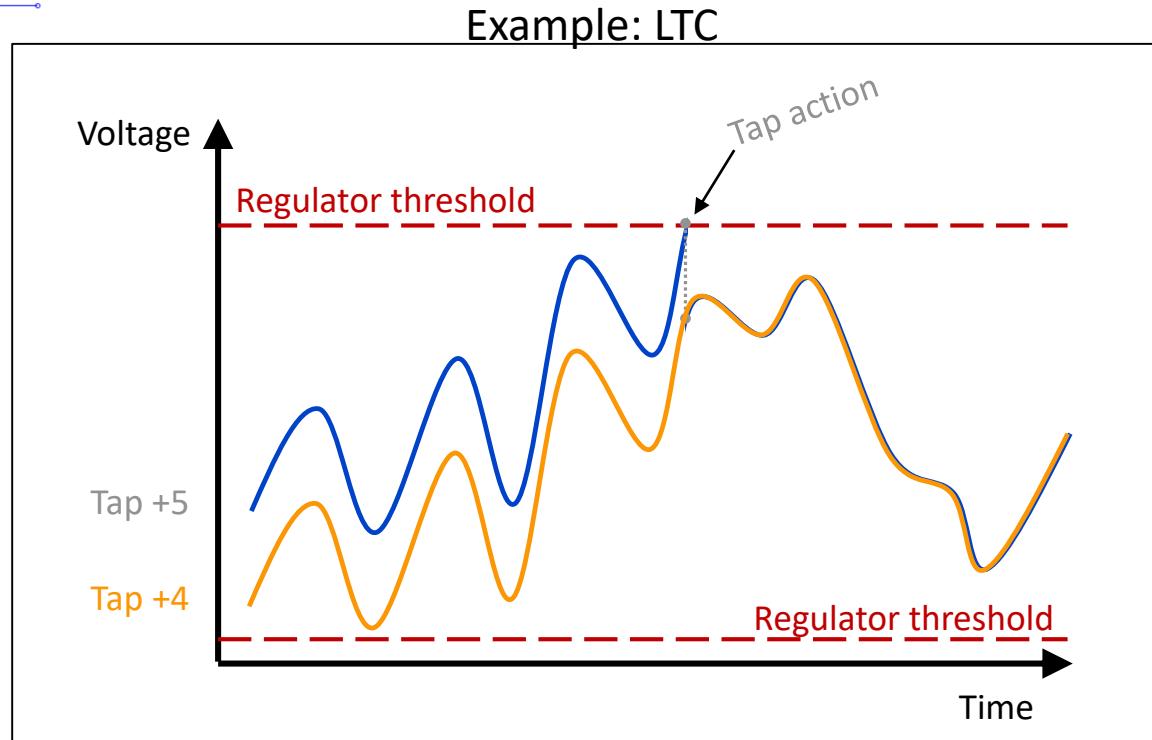


# Quasi-Static Time-Series (QSTS) simulation

- The operation of discrete controls from autonomous controllers can be modeled with a QSTS simulation.



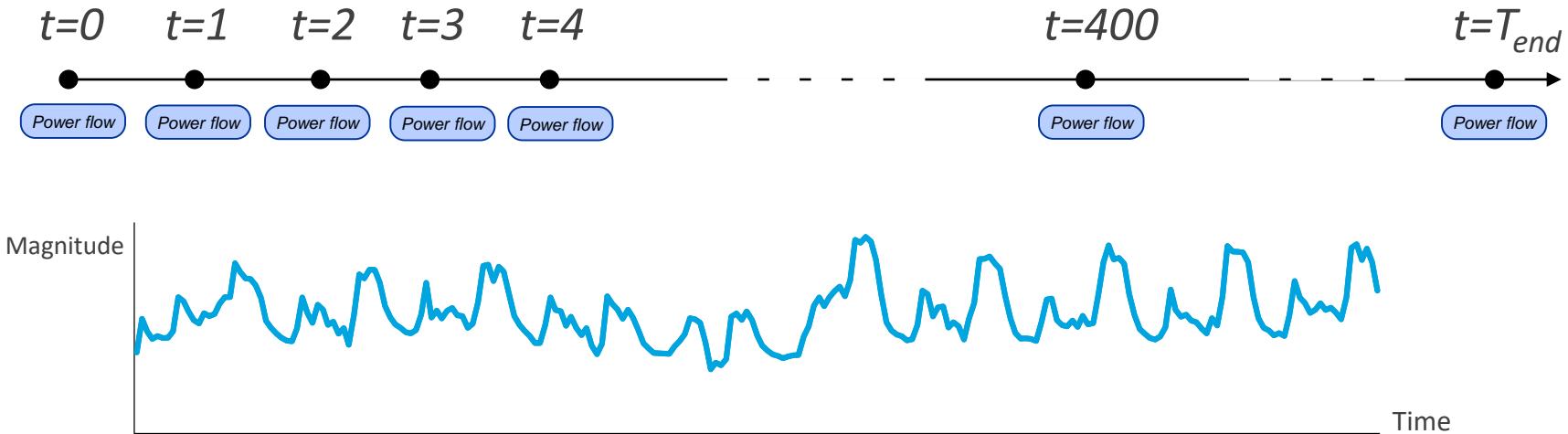
```
new regcontrol.creg4a transformer=reg4a winding=2  
vreg=124 band=2 ptratio=20 ctprim=300 R=0.6 X=1.3
```



# QSTS Applications

The IEEE Std<sup>1</sup> defines a Quasi-Static Time-Series simulation as:

**Quasi-static time-series (QSTS) simulation** – “Quasi-static simulation refers to a sequence of steady-state power flow, conducted at a time step of no less than 1 second but that can use a time step of up to one hour. Discrete controls, such as capacitor switch controllers, transformer tap changers, automatic switches, and relays, may change their state from one step to the next. However, there is no numerical integration of differential equations between time steps.” [IEEE Std 1547.7-2013]

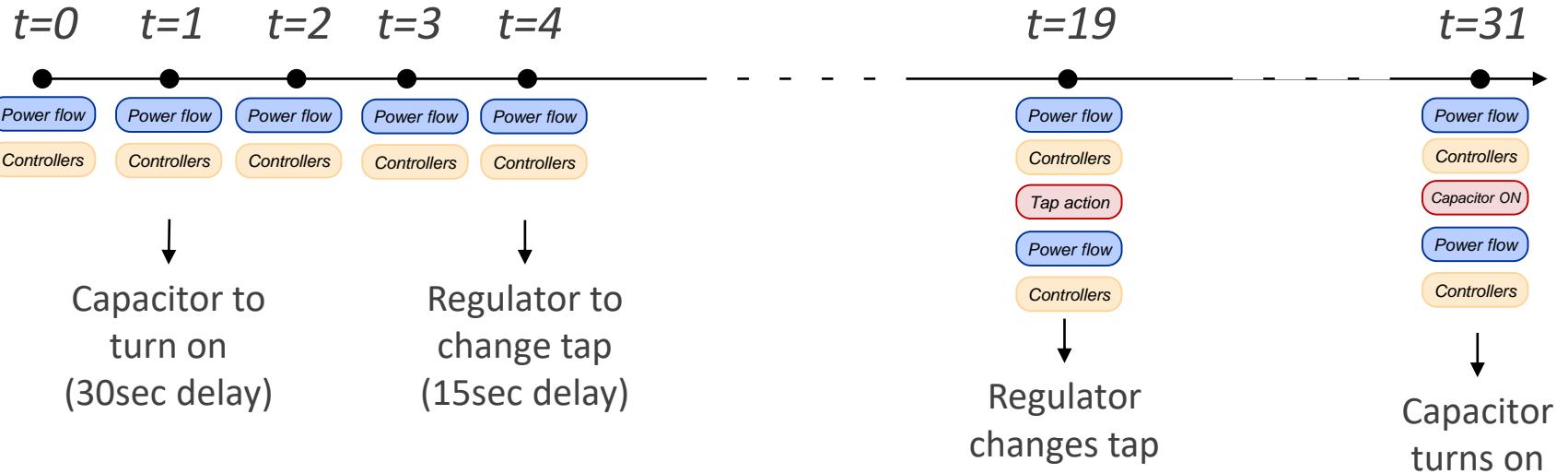


<sup>1</sup> IEEE Std 1547.7-2013. ‘IEEE Guide for Conducting Distribution Impact Studies for Distributed Resource Interconnection’. 2016.

# Dealing with multiple controllers: Control queue

*What if there are a line regulator and a capacitor banks?*

*Which one is the first one to act?*



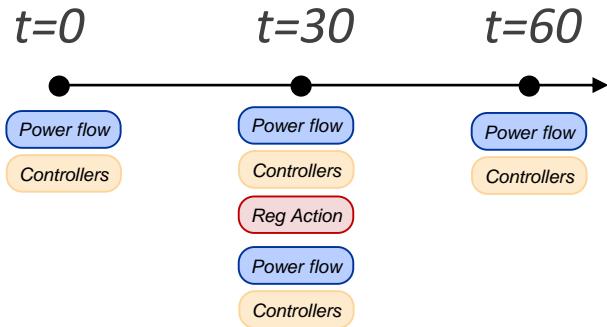
Timestamp	Action to take
$t = 31$	Capacitor to turn on
-	-
-	-
-	-
-	-
-	-

Timestamp	Action to take
$t = 19$	Regulator to change tap +1
$t = 31$	Capacitor to turn on
-	-
-	-
-	-
-	-

Timestamp	Action to take
$t = 19$	Regulator to change tap +1
$t = 31$	Capacitor to turn on
-	-
-	-
-	-
-	-

# OpenDSS QSTS simulation

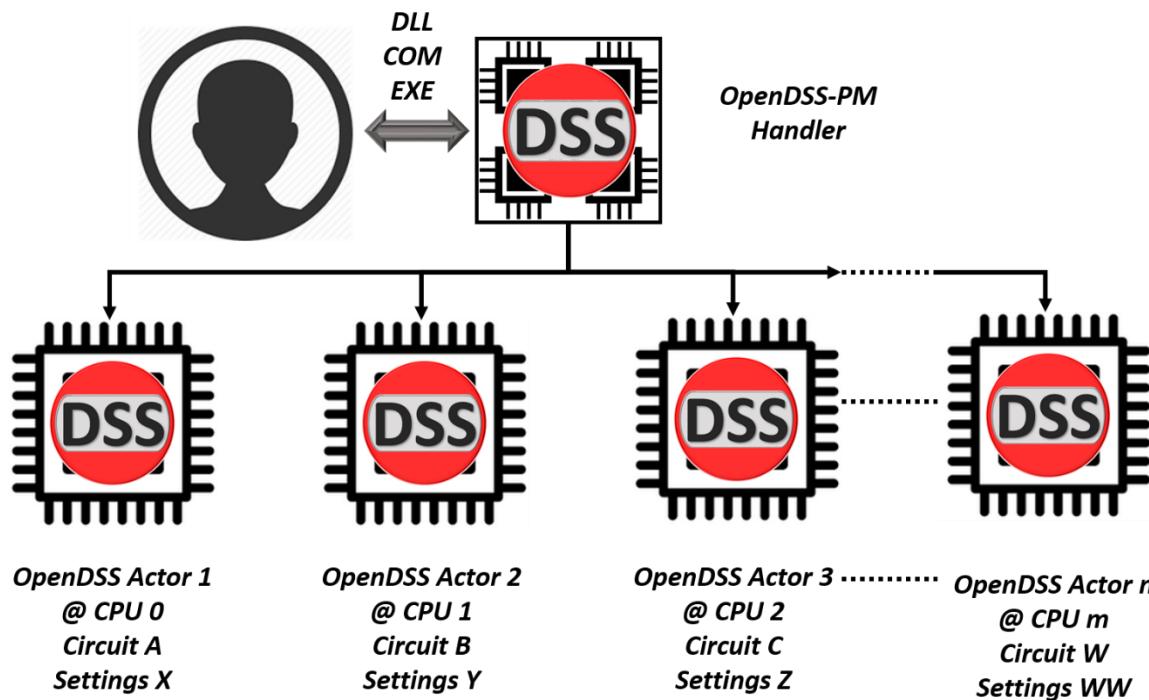
- Set Controlmode={OFF | STATIC | EVENT | TIME}
  - STATIC: time does not advance, and control actions are executed in order of shortest time to action until all actions are cleared from the queue.
  - EVENT: Time is advanced automatically to the time of the event.
  - TIME: Similar to the last slide, the control actions are driven by time.
- A control action in the queue will be removed if the control signal comes back within the controller limits and the timestamp isn't reach.
- OpenDSS command lines:
  - ‘Show controlled’ will show controlled equipment.
  - ‘Show controlqueue’ will show the current control queue.
  - ‘Show eventlog’ will show the past controller actions.



Control queue	
Timestamp	Action to take
$t = 15$	Regulator to change tap +1
$t = 30$	Capacitor to turn on
-	-
-	-
-	-
-	-
-	-

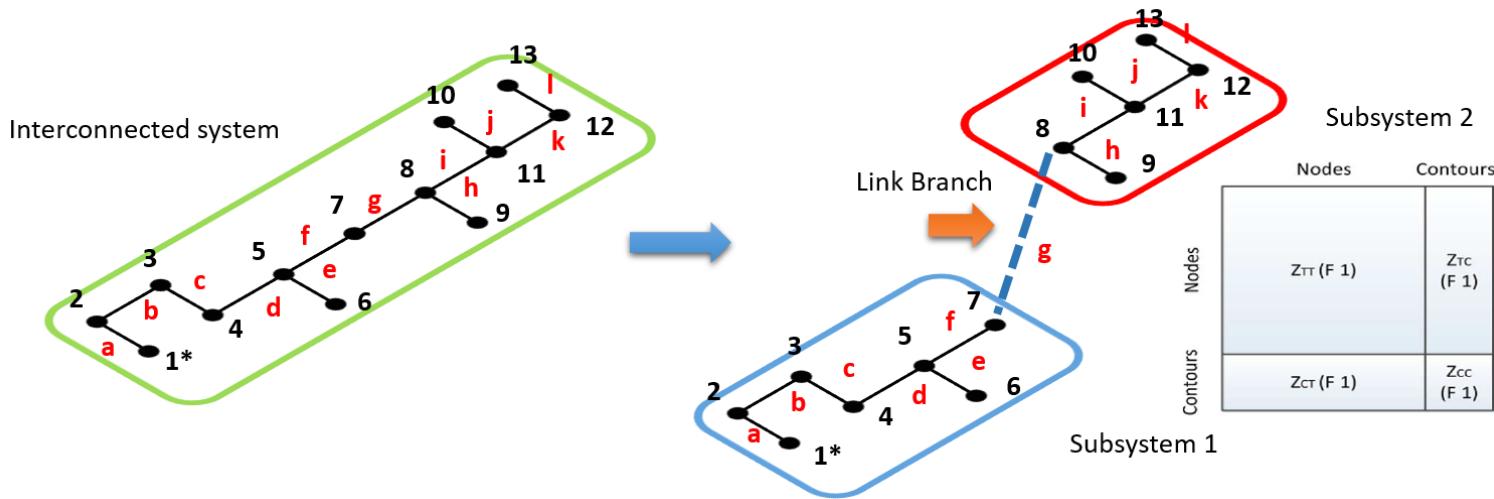
# Parallel computing in OpenDSS

- To further increase the computational speed on large feeder models, a parallel processing is used with OpenDSS **using the actor model**.
- Each actor is created by OpenDSS, runs on a separate processor using separate threads and has its own assigned core and priority (real-time priority for the process and time critical for the thread)

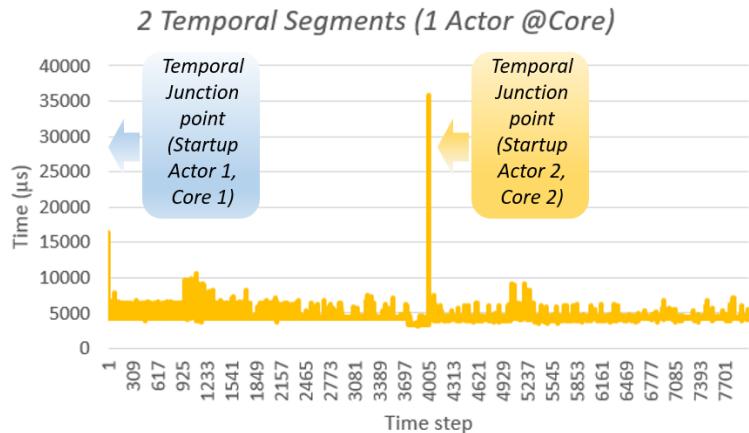
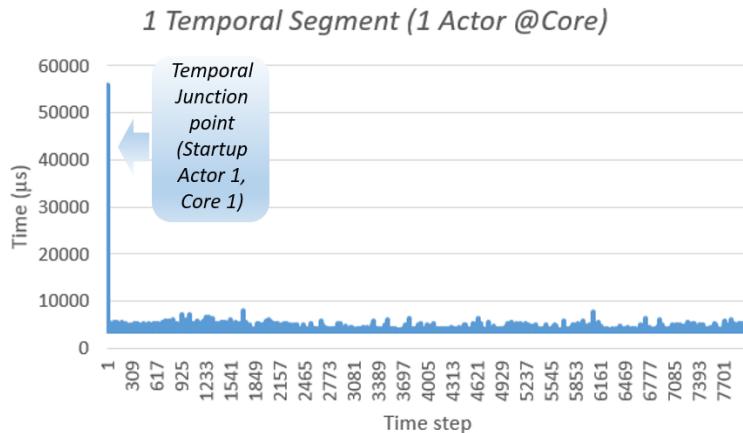


# What can be done with parallel processing in OpenDSS?

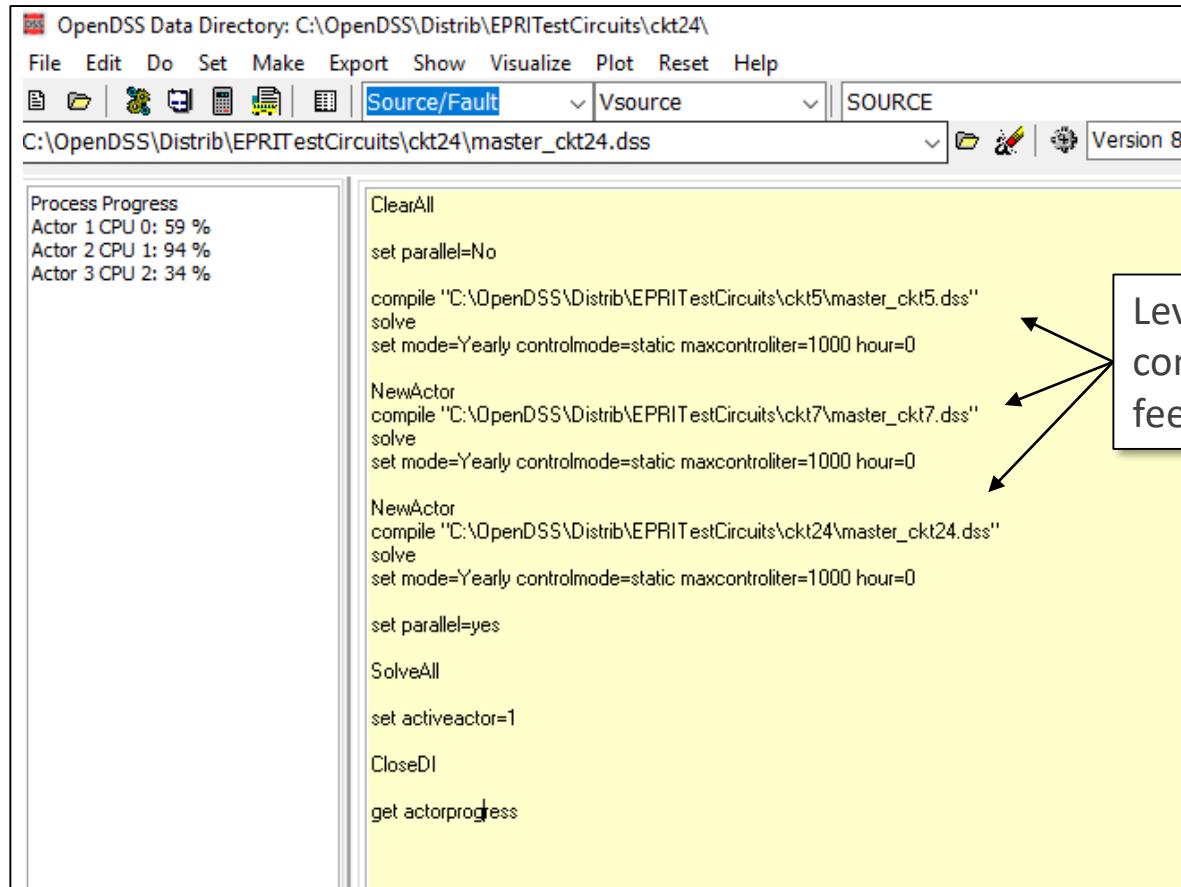
Spatial Parallelization



Temporal Parallelization



# Using parallel processing in OpenDSS



The screenshot shows the OpenDSS software interface. The menu bar includes File, Edit, Do, Set, Make, Export, Show, Visualize, Plot, Reset, and Help. The toolbar includes icons for Source/Fault, Vsource, and SOURCE. The status bar shows the path C:\OpenDSS\Distribution\EPRITestCircuits\ckt24\ and Version 8. The main window displays a script editor with the following code:

```
OpenDSS Data Directory: C:\OpenDSS\Distribution\EPRITestCircuits\ckt24\  
File Edit Do Set Make Export Show Visualize Plot Reset Help  
Source/Fault Vsource SOURCE  
C:\OpenDSS\Distribution\EPRITestCircuits\ckt24\master_ckt24.dss Version 8  
  
Process Progress  
Actor 1 CPU 0: 59 %  
Actor 2 CPU 1: 94 %  
Actor 3 CPU 2: 34 %  
  
ClearAll  
set parallel=No  
compile "C:\OpenDSS\Distribution\EPRITestCircuits\ckt5\master_ckt5.dss"  
solve  
set mode=Yearly controlmode=static maxcontroliter=1000 hour=0  
  
NewActor  
compile "C:\OpenDSS\Distribution\EPRITestCircuits\ckt7\master_ckt7.dss"  
solve  
set mode=Yearly controlmode=static maxcontroliter=1000 hour=0  
  
NewActor  
compile "C:\OpenDSS\Distribution\EPRITestCircuits\ckt24\master_ckt24.dss"  
solve  
set mode=Yearly controlmode=static maxcontroliter=1000 hour=0  
  
set parallel=yes  
  
SolveAll  
  
set activeactor=1  
  
CloseDI  
  
get actorprogress
```

Leveraging parallel processing to concurrently analyzing 3 different feeder models.

The examples for parallel processing (MATLAB and python) can be downloaded from:  
[https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Version8/Distrib/Examples/Parallel\\_Processing/](https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Version8/Distrib/Examples/Parallel_Processing/)

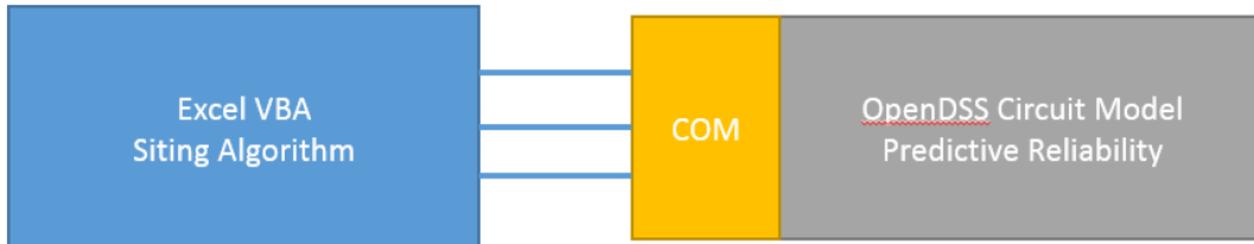
Other examples for LabVIEW are available through the VI Package Manager.

# The evolution of OpenDSS into a parallel computing machine

There is a new set of functions and instructions related with parallel processing, topology analysis and more that can be used using the same DSS command environment

NumCPUs	ClearAll	Tear_Circuit
NumCores	Wait	Export IncMatrix
NewActor	Parallel	Export IncMatrixRows
NumActors	SolveAll	Export IncMatrixCols
ActiveActor	ConcatenateReports	Export BusLevels
CPU	CalcIncMatrix	Init_Diakoptics
ActorProgress	CalcIncMatrix_o	Refine_BusLevels
Abort	CalcLaplacian	Export Laplacian

# Recloser Siting Control Example

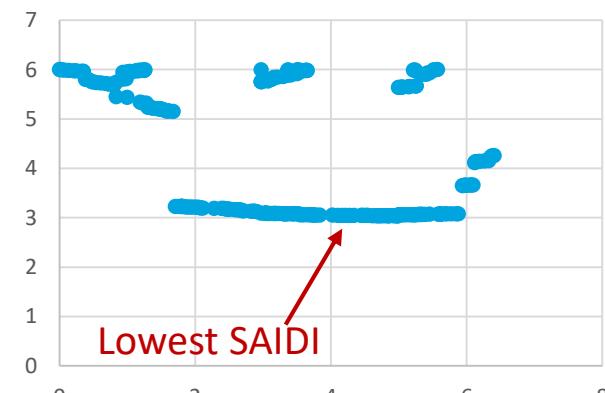
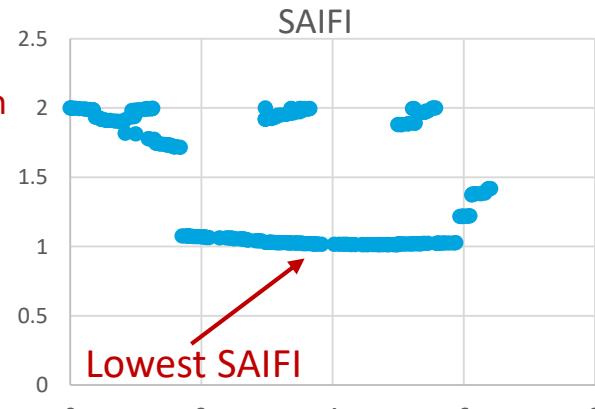
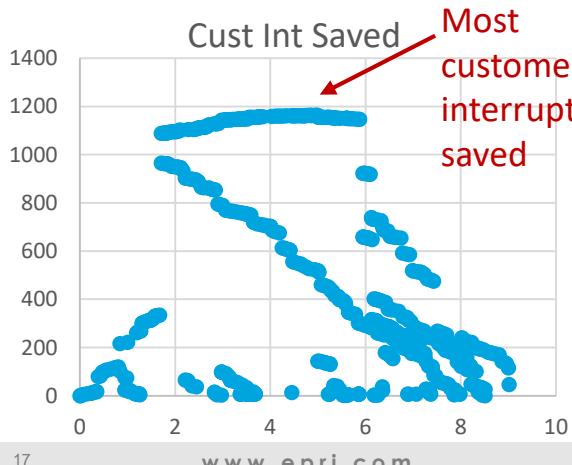
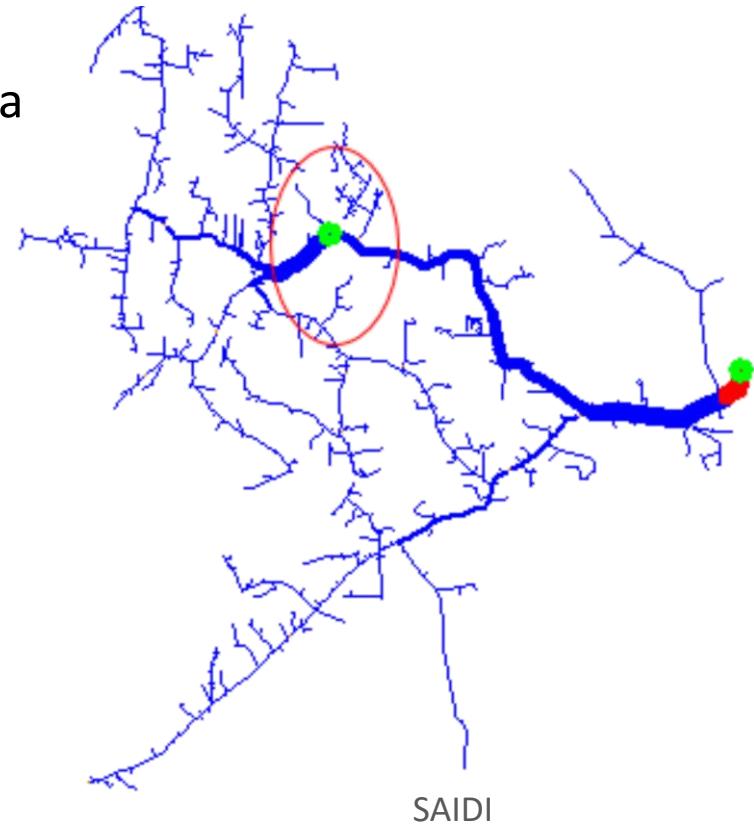


Recloser Siting Control Example											
Example Using IEEE 8500-Node Test Feeder											
3											
4			Start OpenDSS								
5											
6			Execute Run File								
7											
8			Edit Run File								
9											
10			OpenDSS Solve		Result:	C:\Users\prdu001\OpenDSS\Distrib\IEEETestCases\8500-Node\IEEE8500_GeneralCircuit.DSV					
11											
12			Show V LN Nodes	FileEdit @LastExportfile							
			Execute OpenDSS Command(s)		Select Cell(s) Containing DSS Commands then Execute			Go To Siting Sheet			
					Misc. OpenDSS Commands						
					help						
18			set markfuses=yes		Show V LN Nodes ! Show voltages for present solution			var			
19			Relcalc Restore=Yes		show elem fuse			Set recorder=y			
20			Relcalc Restore=NO		show elem relay			Set recorder=n			
21			export branchreliability		show elem recloser				show elem relay		
22			export busreliability						show elem recloser		
23			FileDialog @LastExportfile		Export Sections						
24					FileDialog @LastExportfile						
25					fileedit lines.dss						

Example: "C:\Program Files\OpenDSS\Examples\Excel\Recloser-Siting-Control.xlsx"

# Recloser Siting Control Example

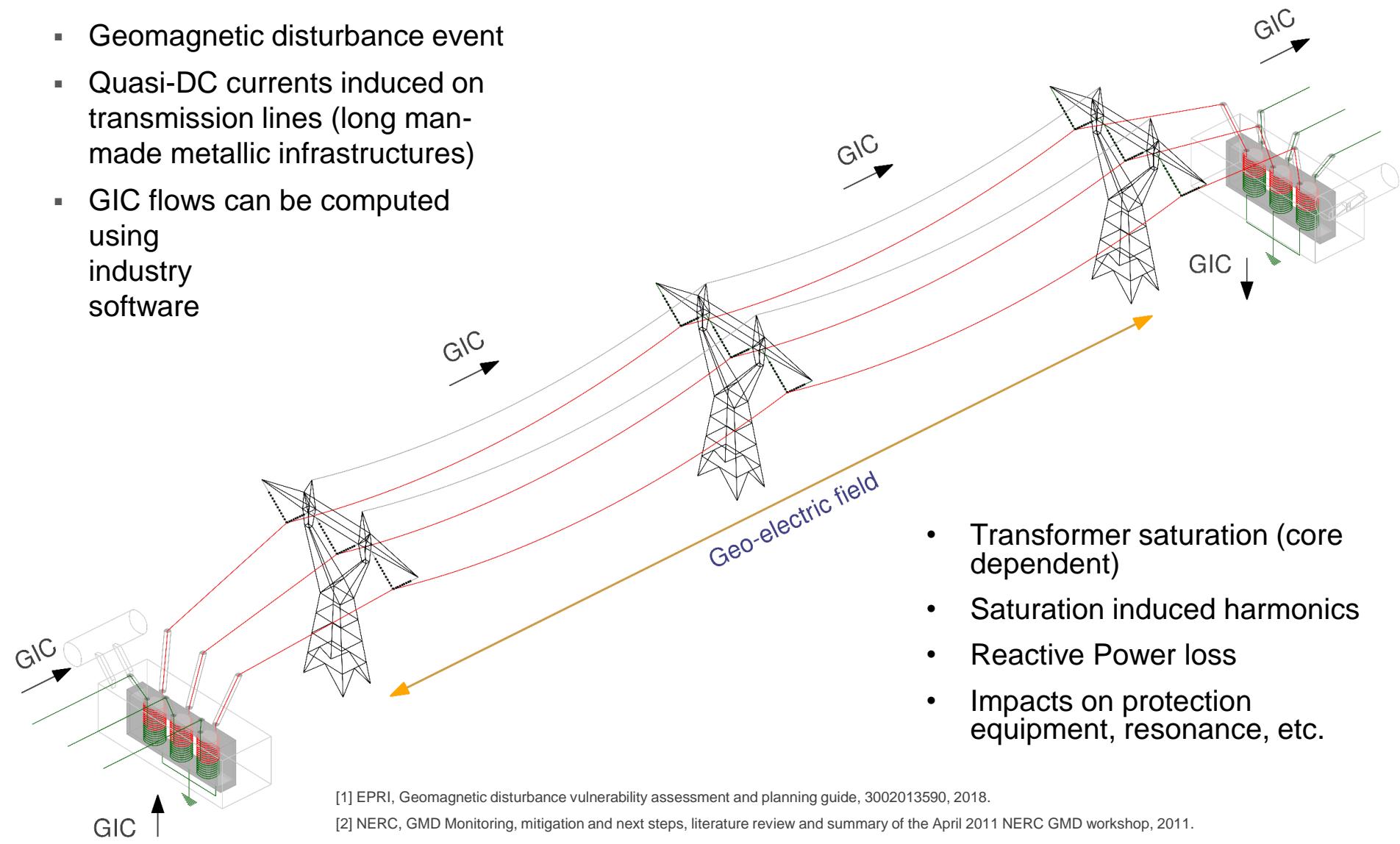
- The objective of the algorithm is to determine a location to reduce the highest number of customer interruption.
- Input data for each element:
  - Line object: fault rate, length, repair
  - Loads: NumCust
  - Location of existing automated switches
- Output of the analysis:
  - Suggested location of new device and resulting SAIFI / SAIDI metrics



# What is GIC?

(Geomagnetically Induced Currents)

- Geomagnetic disturbance event
- Quasi-DC currents induced on transmission lines (long man-made metallic infrastructures)
- GIC flows can be computed using industry software



[1] EPRI, Geomagnetic disturbance vulnerability assessment and planning guide, 3002013590, 2018.

[2] NERC, GMD Monitoring, mitigation and next steps, literature review and summary of the April 2011 NERC GMD workshop, 2011.

[3] IEEE Guide for Establishing Power Transformer Capability while under Geomagnetic Disturbances," in IEEE Std C57.163-2015 , vol., no., pp.1-50, 26 Oct. 2015

# EPRI GICharm v1.0

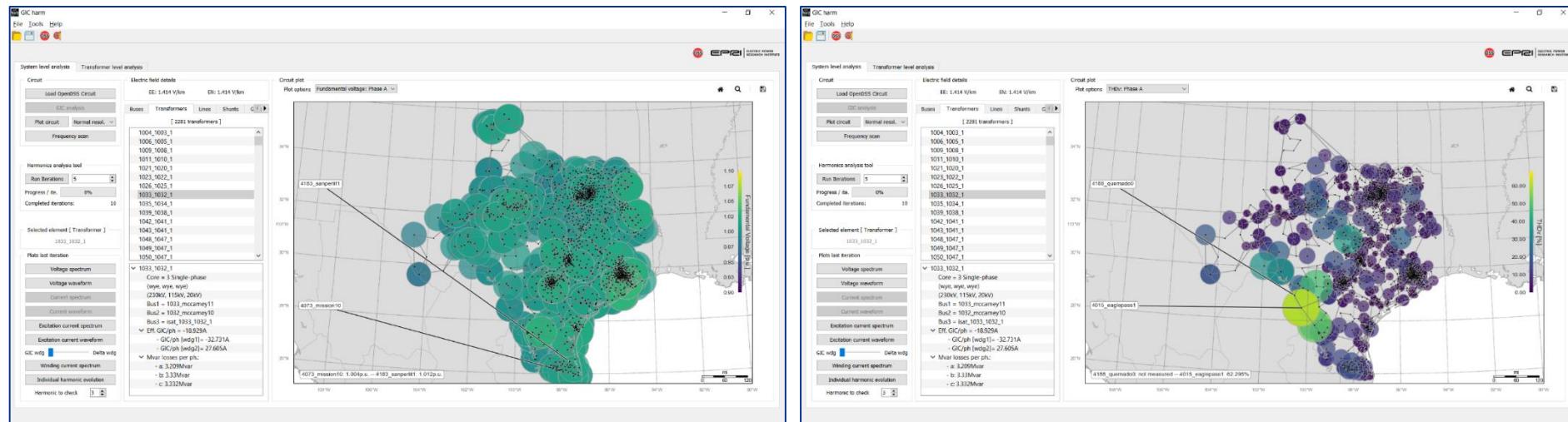
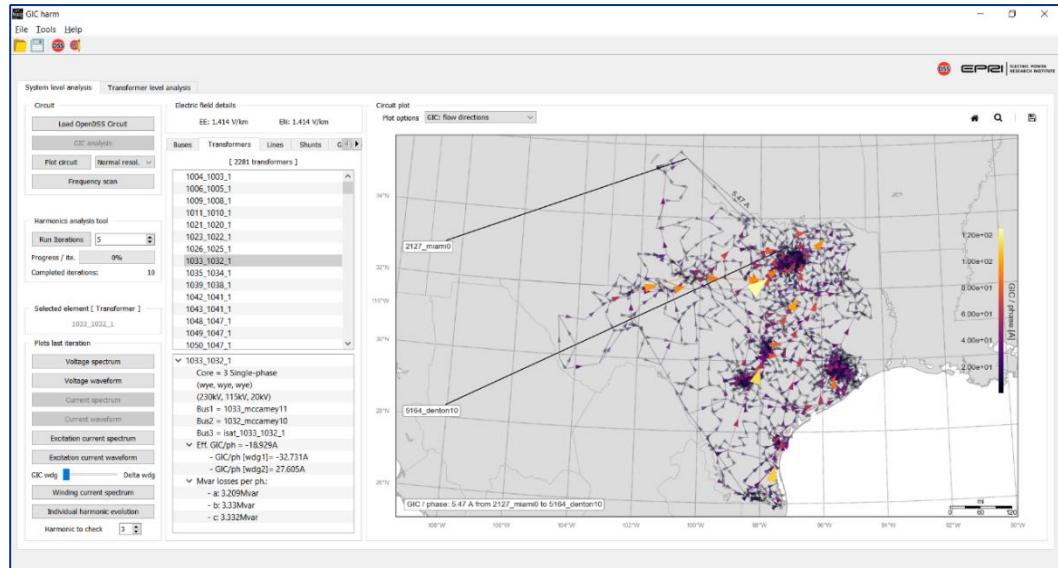
- Software tool to assess the impact of Geomagnetically Induced Currents (GIC) related harmonics
- Beta version available to the public
- Will be released as an Open source software
- Capable of extensive system modeling
- Capable of accurate representation of saturated transformers
- Works with the EPRI OpenDSS simulation software engine
- Accepts system model information from PSS®E vendor software



Available on [epri.com](http://epri.com) Product ID#  
3002014854

# System level Analysis – Explore simulation results

- GUI includes circuit plot capabilities to overlay GIC flows, voltage THD and fundamental voltage data over the circuit footprint



A. B. Birchfield, T. Xu, and T. J. Overbye, "Power flow convergence and reactive power planning in the creation of large synthetic grids," in IEEE Transactions on Power Systems, 2018.

# Applying OpenDSS in R&D

# Outline

## Available tools:

- OpenDSS
- OpenDSS-G
- Excel VBA
- MATLAB toolbox
- Python toolbox

## Available feeder models:

- IEEE models
- EPRI models

## Available datasets:

- Load / PV profiles
- 3<sup>rd</sup> party datasets

# Scripts in OpenDSS

OpenDSS Data Directory: C:\Program Files\OpenDSS\IEEETestCases\123Bus\

File Edit Do Set Make Export Show Visualize Plot Reset Help

C:\Program Files\OpenDSS\IEEETestCases\123Bus\IEEE123Master.dss

```

Results for Actor ID # 1
CPU selected : 0
Status = SOLVED
Solution Mode = Snap
Number = 100
Load Mult = 1.000
Devices = 237
Buses = 136
Nodes = 278
Control Mode = STATIC
Total Iterations = 19
Control Iterations = 6
Max Sol Iter = 4

- Circuit Summary -
Year = 0
Hour = 0
Max pu. voltage = 1.05
Min pu. voltage = 0.97921
Total Active Power: 3.61524 MW
Total Reactive Power: 1.31151 Mvar
Total Active Losses: 0.0959769 MW, (2.655 %)
Total Reactive Losses: 0.192504 Mvar
Frequency = 60 Hz
Mode = Snap
Control Mode = STATIC
Load Model = PowerFlow

IREGULATORS - REDIRECT TO DEFINITIONS FILE
! This file contains definitions for the remainder of regulators on the feeder:
Redirect IEEE123Regulators.DSS

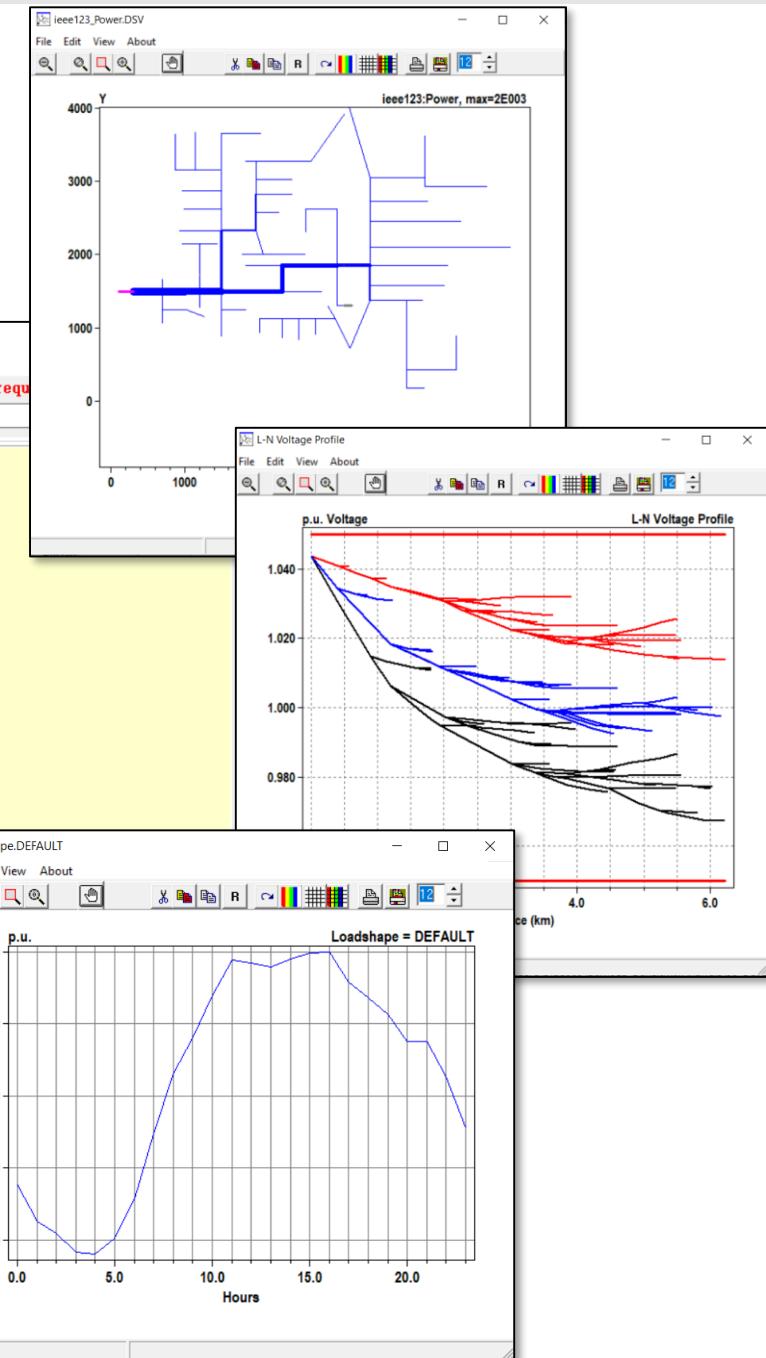
! SPOT LOADS -- REDIRECT INPUT STREAM TO LOAD DEFINITIONS FILE
Redirect IEEE123Loads.DSS

! All devices in the test feeder are now defined.
!
! Many of the voltages are reported in per unit, so it is important to establish the base voltages at each bus so that we can compare with the result with greater ease.
! We will let the DSS compute the voltage bases by doing a zero-load power flow.
! There are only two voltage bases in the problem: 4160V and 480V. These must be expressed in kV

Set VoltageBases = [4.16, 0.48] ! ARRAY OF VOLTAGES IN KV
CalcVoltageBases ! PERFORMS ZERO LOAD POWER FLOW TO ESTIMATE VOLTAGE BASES
solve

Main IEEE123Master.dss
Messages OpenDSS - C:\Program Files\OpenDSS\IEEETestCases\123Bus\IEEE123Master.dss
Summary Results
Memory: 59296K Circuit Status: SOLVED Total Iterations = 19, Control Iterations = 6, Max Solution Iteration = 4

```

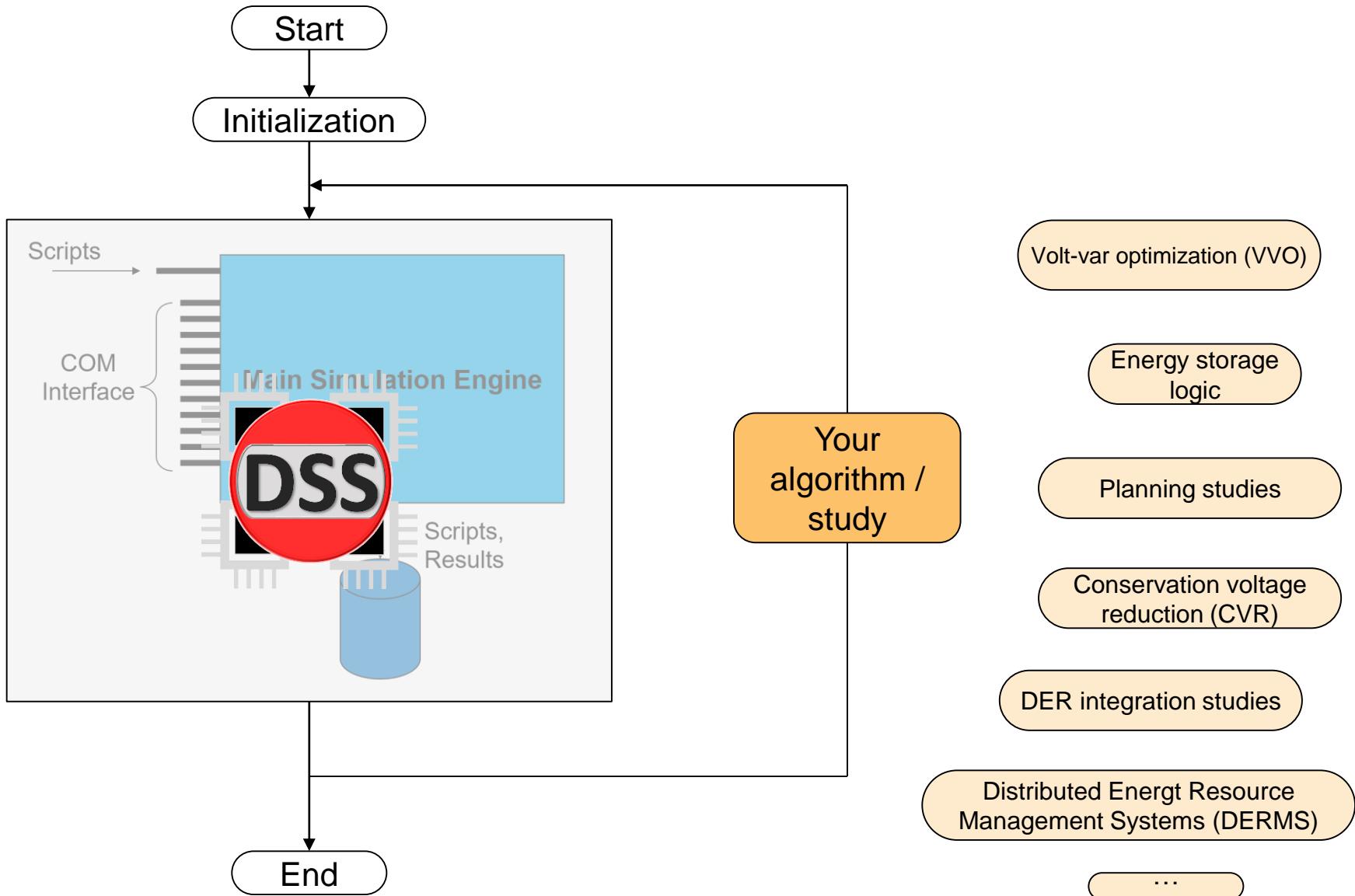


# OpenDSS-G

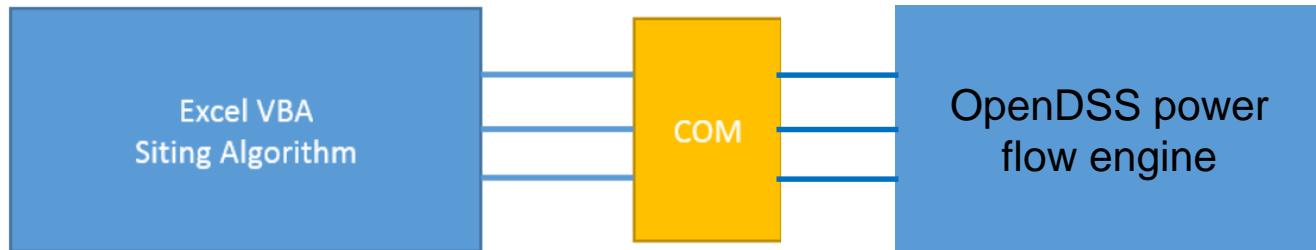


See session #2 from this virtual training

# Using OpenDSS for its power flow engine



# Excel VBA



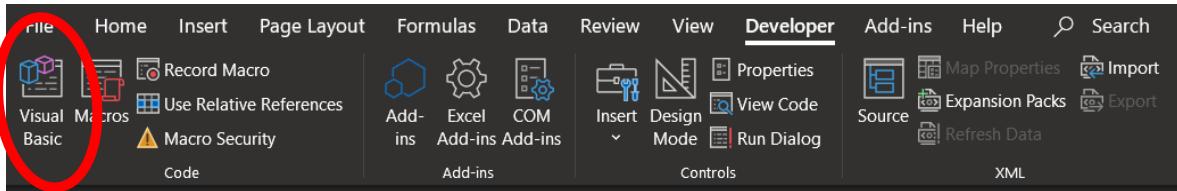
Start DSS

1	Start DSS	Version: Version 8.6.1.1 (32-bit build); License Status: Open	C:\Users\prdu001\OpenDSS\Test\SimpleStorageTest.dss
2			C:\Users\prdu001\OpenDSS\Distribution\TEMCGenmodels\Model_5Master.DSS
3			C:\Users\prdu001\OpenDSS\Test\PVSystemTest-Duty.dss
4			
5			
6	Run File Path Name:	C:\Users\prdu001\OpenDSS\Distribution\IEEETestCases\8500-Node\Run_8500Node.dss	[C:\Users\prdu001\OpenDSS\Distribution\BenYork\FRT12 Model_031516\FRT12_CKT.dss]
		Execute the Run File	
		Edit	
		Solve the Circuit	
14	Load the Seq Voltages	Load the a + jb Volt Sheet	C:\Users\prdu001\OpenDSS\Distribution\IEEETestCases\123Bus\Run_MonteCarloFault.dss
15			C:\Users\prdu001\OpenDSS\Distribution\IEEETestCases\8500-Node\Run_8500Node.dss
16			C:\Users\prdu001\OpenDSS\Distribution\WesCofax\Run_Master_Storage_50.DSS
17	Load the Seq Currents	Load the Load Powers	C:\Users\prdu001\OpenDSS\Distribution\IEEETestCases\13Bus\IEEE13test.dss
			C:\Users\prdu001\OpenDSS\Distribution\EPRI\EPRI Test Circuits\ckt5\Run_ckt5.dss
			C:\Users\prdu001\OpenDSS\Distribution\IEEETestCases\13Bus\IEEE13Nodeckt.dss
			(C:\Users\prdu001\OpenDSS\Distribution\IEEETestCases\123Bus\IEEE123Master.DSS)
			C:\Users\prdu001\Projects\EPRI\GIC\Harmonics2018\OpenDSSDemo\TestCircuitHarrn500kV-2.dss
			C:\Users\prdu001\OpenDSS\Distribution\EPRI Test Circuits\ckt24\master_ckt24.dss
			Export mon TRYD
			New Energymeter.M1 Line.L115.1
			Energymeter.m1.action=z
25	Result:		
26			show buses
27	Some Common Commands:		Export voltages
28			
29	Set MarkRel=yes Markrelay=yes	clear	Get datapath
30	? Energymeter.m1.saifi	show event	plot zone
31	Plot Circuit	show overload	plot profile
32	show v In nodes	show element capcontrol	Export Sections
33	show curr elem		File>Edit@Loadfile

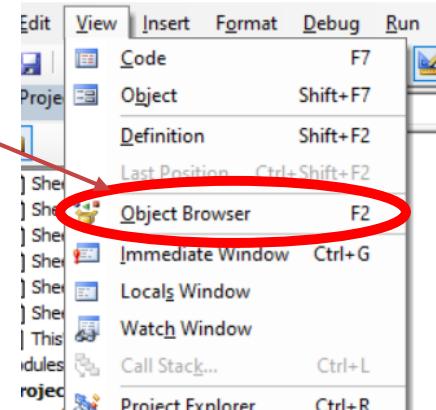
Example: "C:\Program Files\OpenDSS\Examples\Excel\DSSDriver8.xlsx"

# Excel VBA – Object Browser

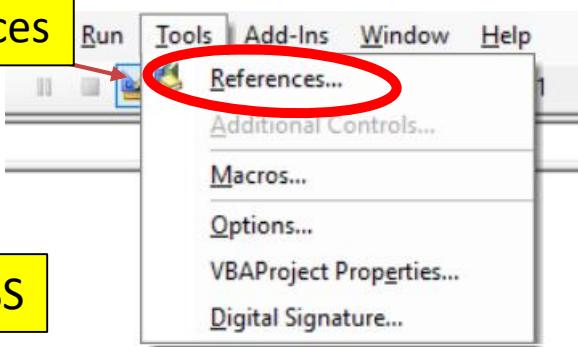
Open VBA



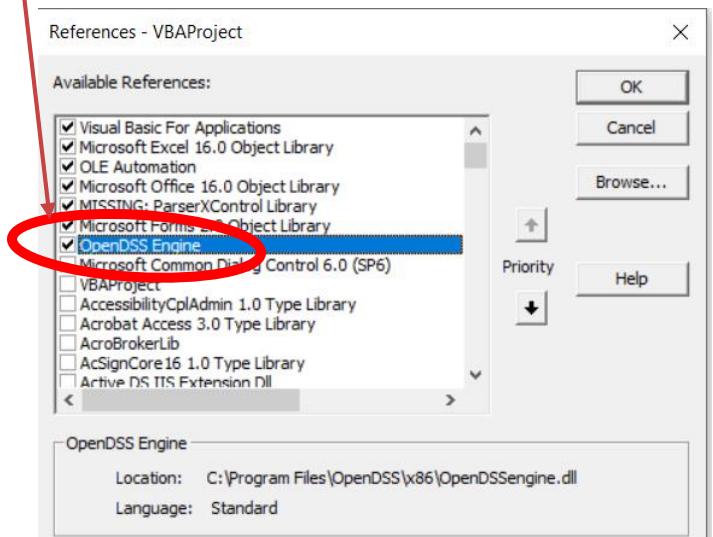
Open Object Browser



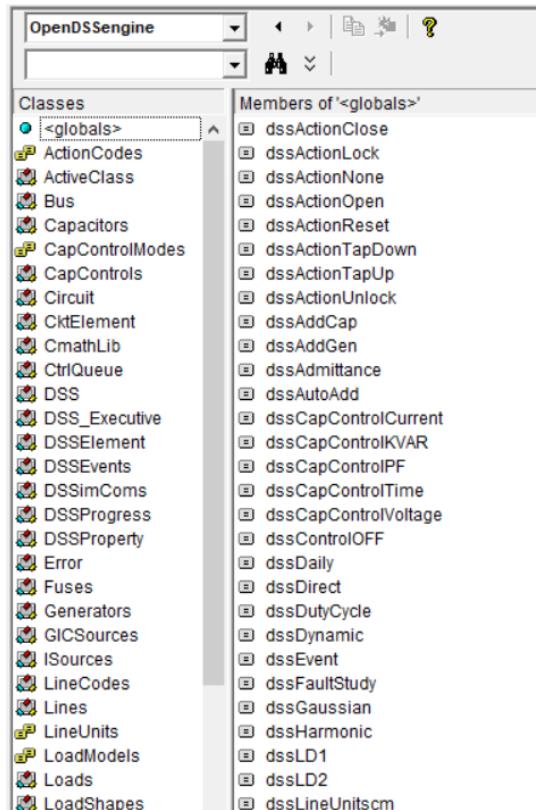
Select References



Select OpenDSS

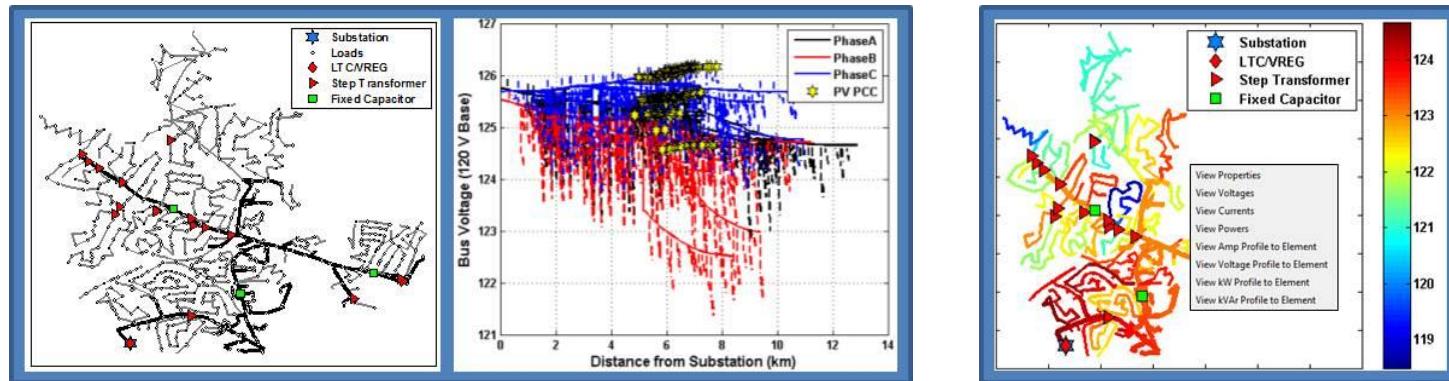
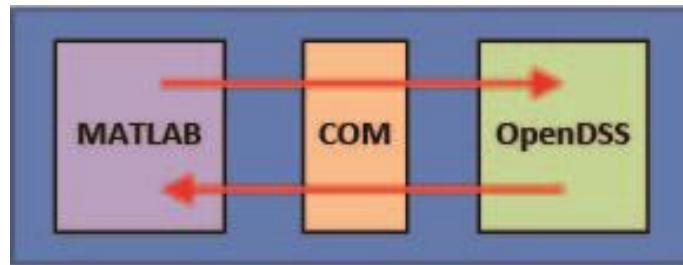


Object Browser



# MATLAB integration: GridPV Toolbox

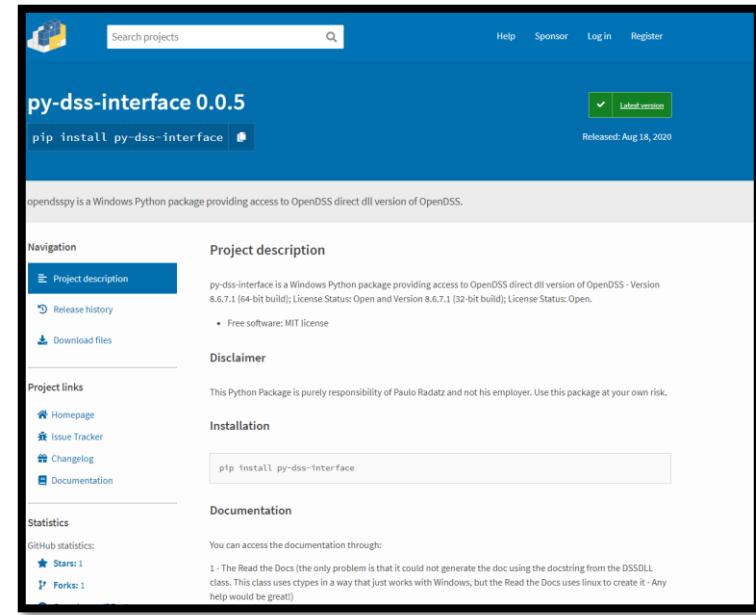
- Set of MATLAB function created by Sandia National Laboratory
- To model and simulate the integration of distributed generation into the electric power system and to determine the impacts on the distribution system for highly variable generation
- Available at: <https://pvpmc.sandia.gov/applications/gridpv-toolbox/>



# Python integration: py-dss-interface

- Python Package that works on Windows
- Uses the official OpenDSS DirectDLL version
  - Version 8.6.7.1 comes with the Package
  - Users can use their OpenDSS version as well
- Created based on Direct connection Shared Library (DLL) for OpenDSS doc by Davis Montenegro

- Installing from PyPI
  - *pip install py-dss-interface*



# Getting Started

User can pass the OpenDSS path as argument:  
"C:/Program Files/OpenDSS"

import package

Create dss Obj

Use text method of dss

Use solution\_solve  
method of dss

Use circuit\_allbusvolts  
method of dss

```
# First import the Package
import py_dss_interface

# Creates an OpenDSS object
dss = py_dss_interface.DSSDLL()

# Select the DSS model
dss_file = r"C:\MeuTCC\Paulo_Example\DSSFiles\MASTER_RedeTeste13Barras.dss"

# Compile
dss.text("compile {}".format(dss_file))

# Solve
dss.solution_solve()

# Show Voltage Report
dss.text("show voltages")

# Get all buses voltages
allbusvolts = dss.circuit_allbusvolts()

print(dss.circuit_allbusvolts())
```

IDE Code Completion is quite useful to select methods of dss

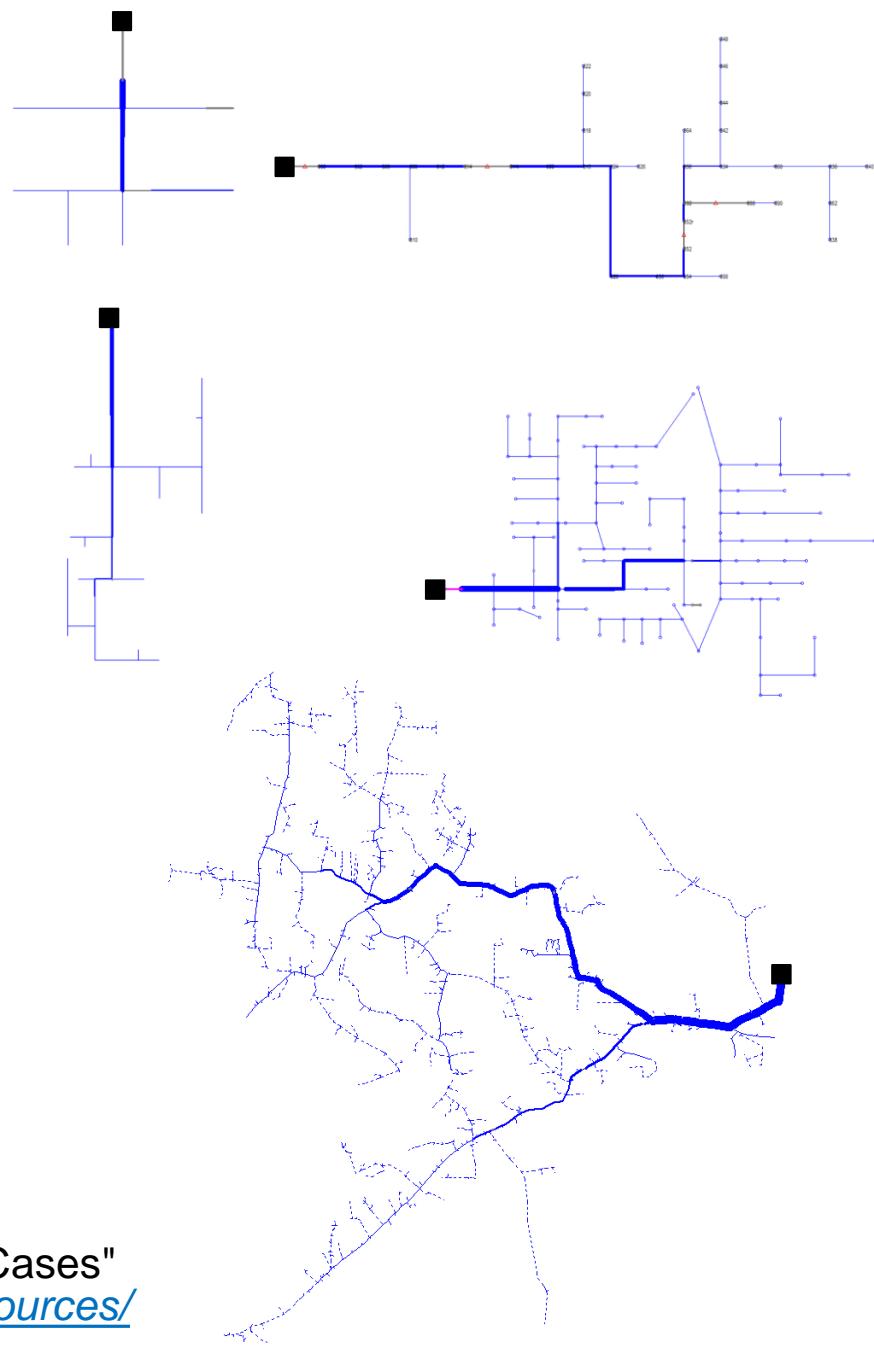
# Know more about py-dss-interface

## ▪ Resources

- PyPI (Python Package Index): <https://pypi.org/project/py-dss-interface/>
- GitHub: [https://github.com/PauloRadatz/py\\_dss\\_interface](https://github.com/PauloRadatz/py_dss_interface)
- Doc: <https://py-dss-interface.readthedocs.io/en/latest/usage.html>
- OpenDSS\_Direct\_DLL.pdf: [https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Version8/Distrib/Doc/OpenDSS\\_Direct\\_DLL.pdf](https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Version8/Distrib/Doc/OpenDSS_Direct_DLL.pdf)

# IEEE test feeders

- 13-bus feeder: simple feeder model to test common features
- 34-bus feeder: Actual feeder located in Arizona, which is highly loaded.
- 37-bus feeder: Actual feeder in California with delta configuration.
- 123-bus feeder: Test feeder with significant voltage drop requiring voltage regulation.
- 8500-node feeder: Large scale feeder intended to test the scalability of an algorithm. Secondaries are modeled.

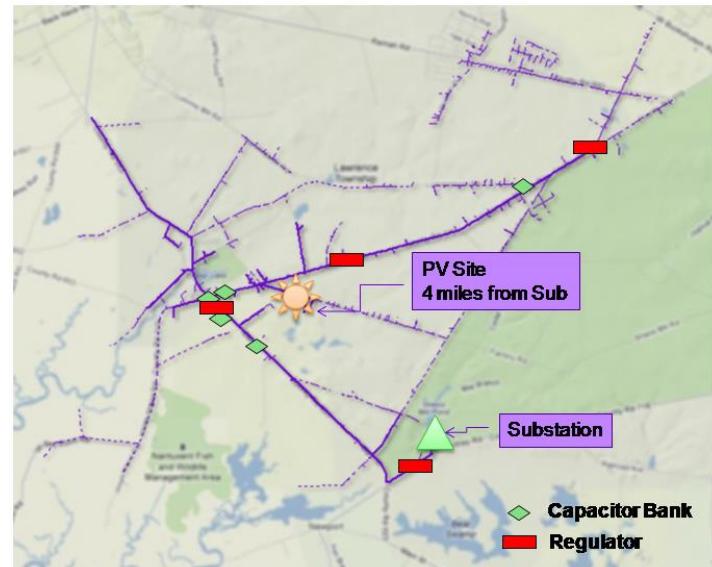
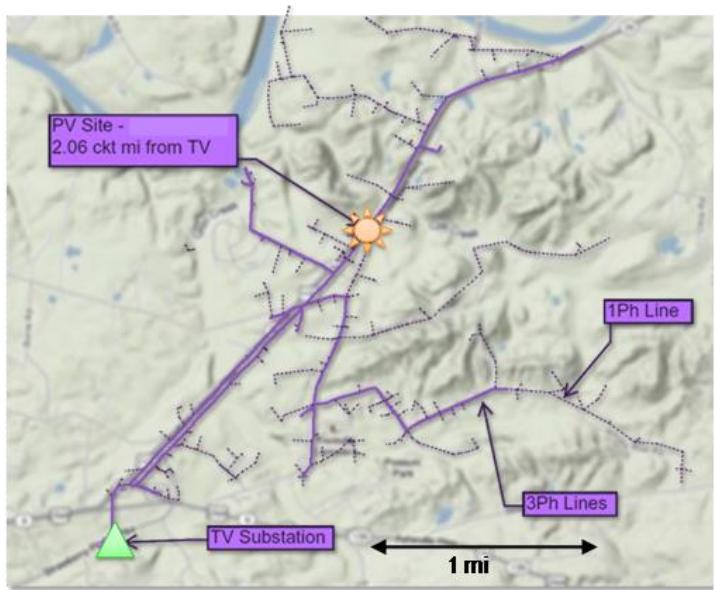


"C:\Program Files\OpenDSS\IEEETestCases"

Available at: <https://site.ieee.org/pes-testfeeders/resources/>

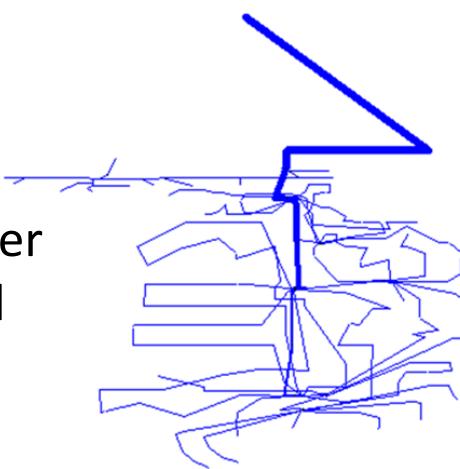
# EPRI test feeders

- Feeder J1: Located in northeastern US feeder with 1.7MW of customer-owned PV systems.



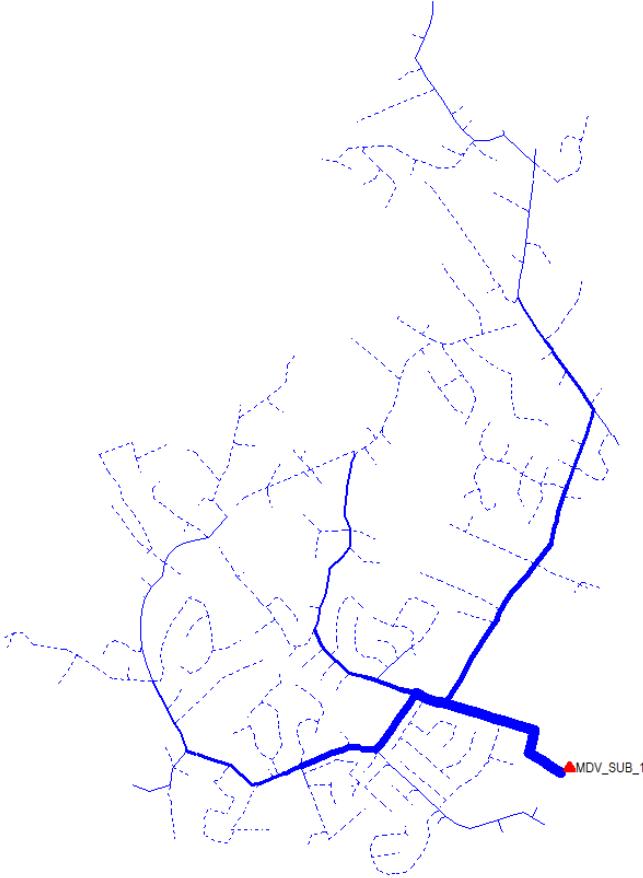
- Feeder K1: Located in southeastern US with a 1.0MW customer-owned PV system.

- Feeder M1: Short and compact feeder with 1500 residential customers and radio-controlled capacitor banks.



Available at: <https://dpv.epri.com/index.html>

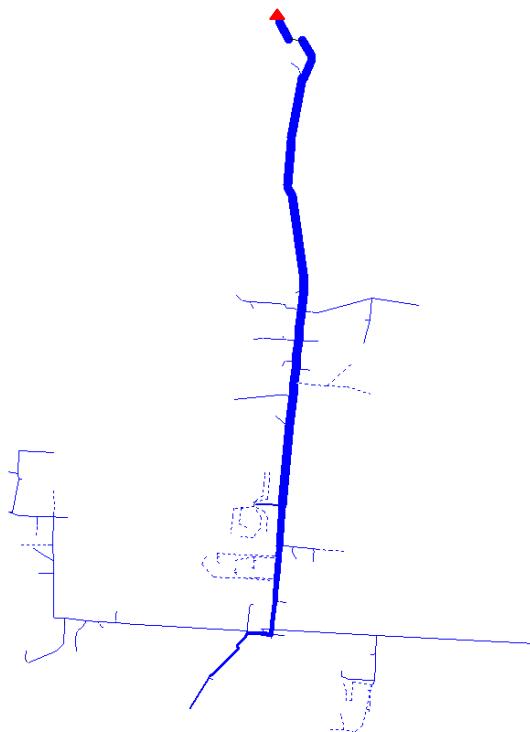
# EPRI test feeders (cont'd)



EPRI Ckt5

*Primary voltage: 12.5kV*

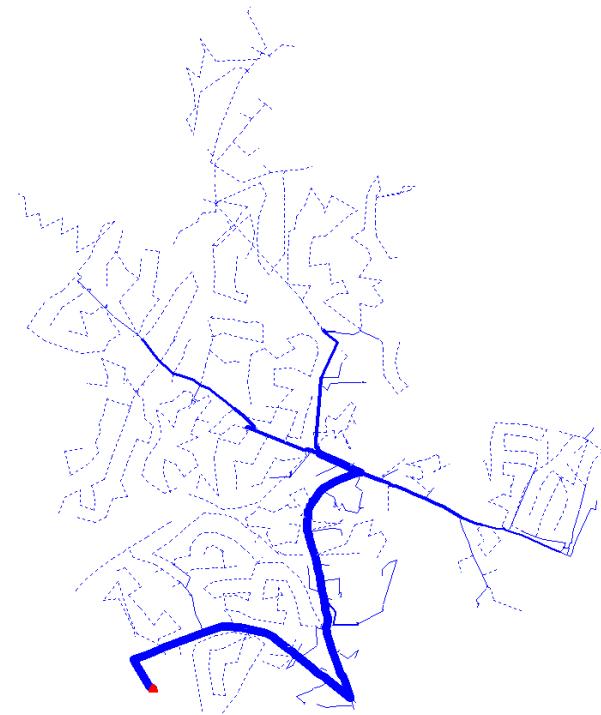
*# of feeders: 1*



EPRI Ckt7

*Primary voltage: 12.5kV*

*# of feeders: 14*



EPRI Ckt24

*Primary voltage: 34.5kV*

*# of feeders: 2*

Available at: "C:\Program Files\OpenDSS\EPRTITestCircuits"

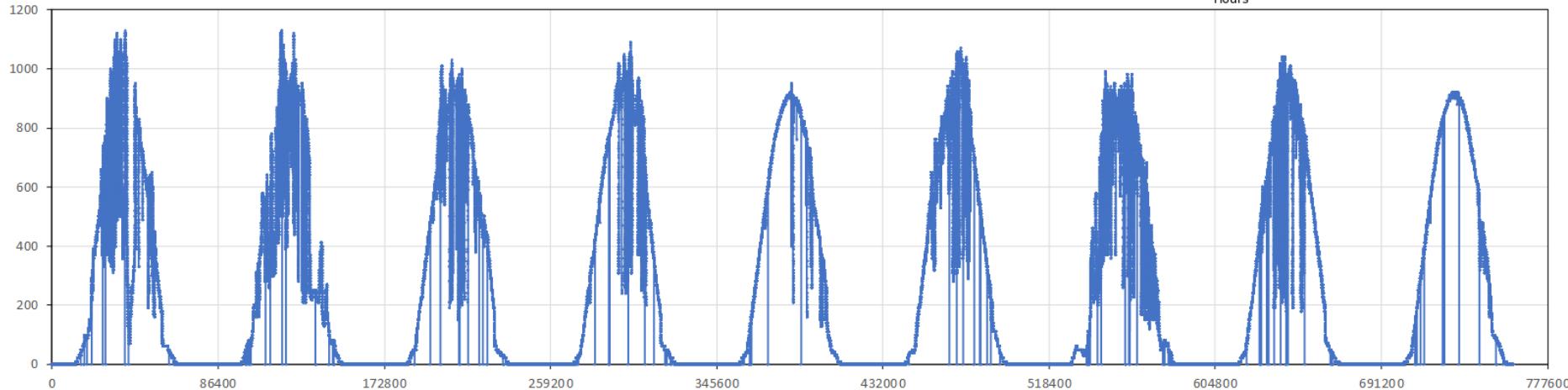
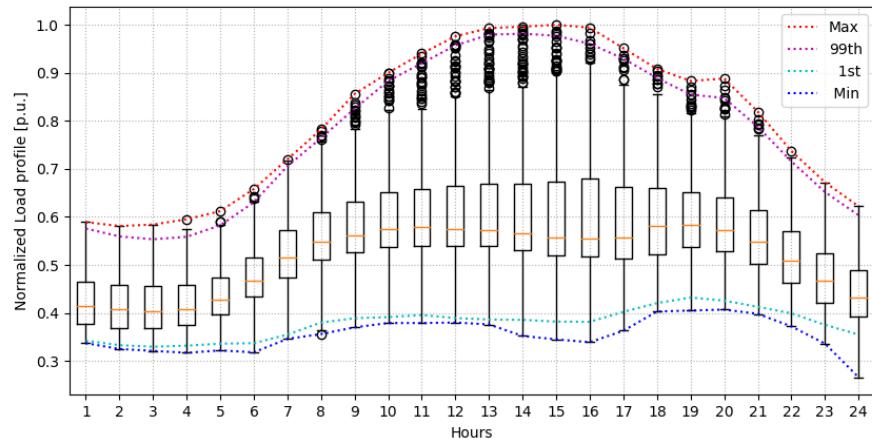
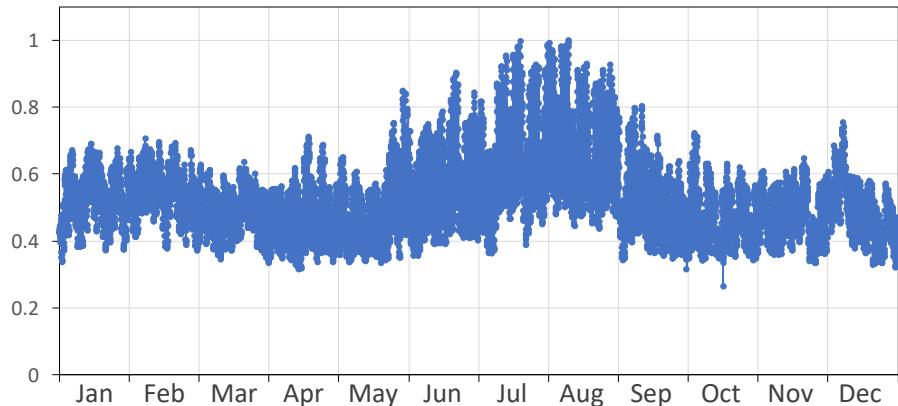
# Datasets

- Load profiles: (available with feeder model)

- IEEE 123 bus: ‘paperloadshape.txt’
- EPRI ckt5: ‘loadshape\_ckt5.dss’
  - Residential load profile
  - Small & Medium commercial load profiles

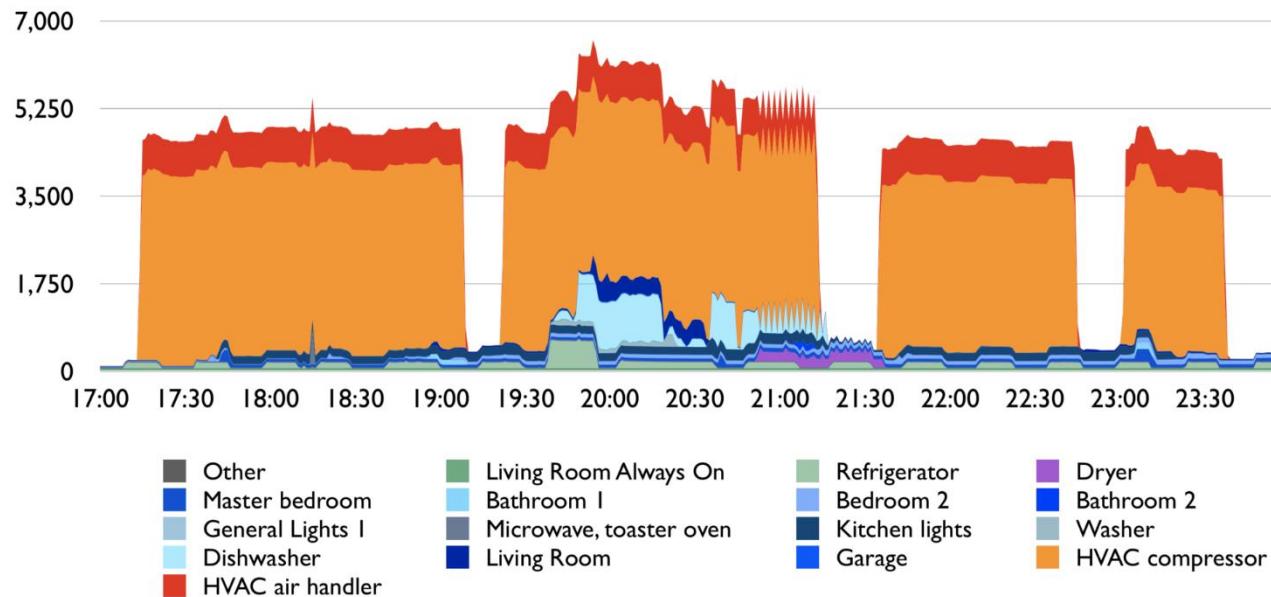
- PV profiles:

- EPRI models: (available at: [dpv.epri.com/](http://dpv.epri.com/))
  - Resolutions: 1 sec, 1-, 15-, 60-min
- NREL dataset: (available at: [pvwatts.nrel.gov/](http://pvwatts.nrel.gov/))
  - Location-specific TMY data at 1hr resolution



# 3<sup>rd</sup> party datasets: Pecan Street

- Available at: <https://www.pecanstreet.org/dataport/about/>
- Dataport provides access to a variety of residential energy and water data including:
  - Whole-home and circuit-level energy use,
  - Appliance use,
  - Solar generation,
  - EV charging behavior,
  - HVAC use, etc.



<https://www.pecanstreet.org/wp-content/uploads/2019/01/1-minute.png>

# 3<sup>rd</sup> party datasets: Centre for Renewable Energy Systems Technology (CREST)

- Available at: <https://www.lboro.ac.uk/research/crest/demand-model/>
- High-resolution stochastic model of domestic thermal and electricity demand.
- Produces one-minute resolution demand data, disaggregated by end-use.
- Using a bottom-up modelling approach based on patterns of active occupancy and daily activity profiles

The screenshot shows the Loughborough University website for the Centre for Renewable Energy Systems Technology (CREST). The top navigation bar includes links for University home, Prospective students, International, News and events, About us, Schools and departments, Research, and Working with business. The main content area features a green banner with the text "Centre for Renewable Energy Systems Technology (CREST)". Below the banner, a breadcrumb trail shows the path: University home > Research > Centre for Renewable Energy Systems Technology (CREST) > CREST Demand Model. The main content section is titled "CREST Demand Model" and contains a large image of several lightbulbs. To the left is a sidebar with links to CREST Homepage, About, News and events, Research, Study, Distance Learning with CREST, Capabilities, PV Measurement and Calibration Laboratory, People, and Contact us. The right sidebar is titled "Latest News" and lists three items: "Vote for CREST to be the winners of the CALIBRE Awards" (20 November 2019), "REST students to take part in the Efficiency for Access Design Challenge" (2 October 2019), and "UK-India Joint Virtual Clean Energy Centre Conference" (1 October 2019). A small "EPRIS" logo is visible in the bottom right corner of the slide.

# How is OpenDSS used ?

## DER integration studies:

- Large-scale **PV systems** (centralized),
- Residential rooftop **PV systems** (distributed),
- **Wind** turbines,
- **Electric vehicles**,
- Customer-owned **storage**,
- Large-scale energy **storage**, etc.

## ▪ Planning studies:

- Time-varying feeder behaviors,
- Load modeling: (load allocations, load growth, AMI data, etc.),
- System reliability study, etc.

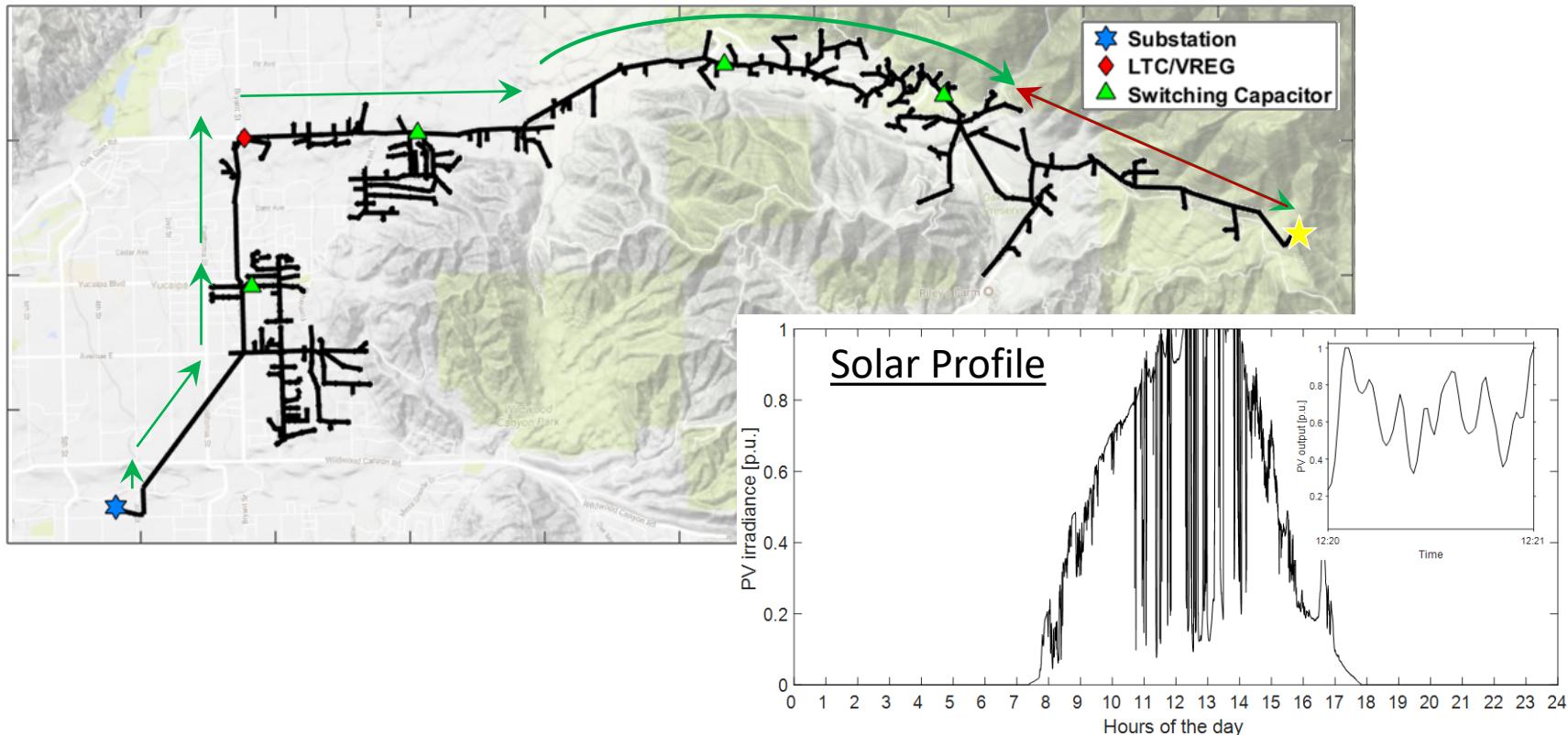
## ▪ Advanced System Controls:

- Distributed Energy Resource Management Systems (DERMS),
- Volt-var optimization (VVO),
- Conservation Voltage Reduction (CVR),
- Fault Location, Isolation, and Service Restoration (FLISR), etc.

# Detailed interconnection studies

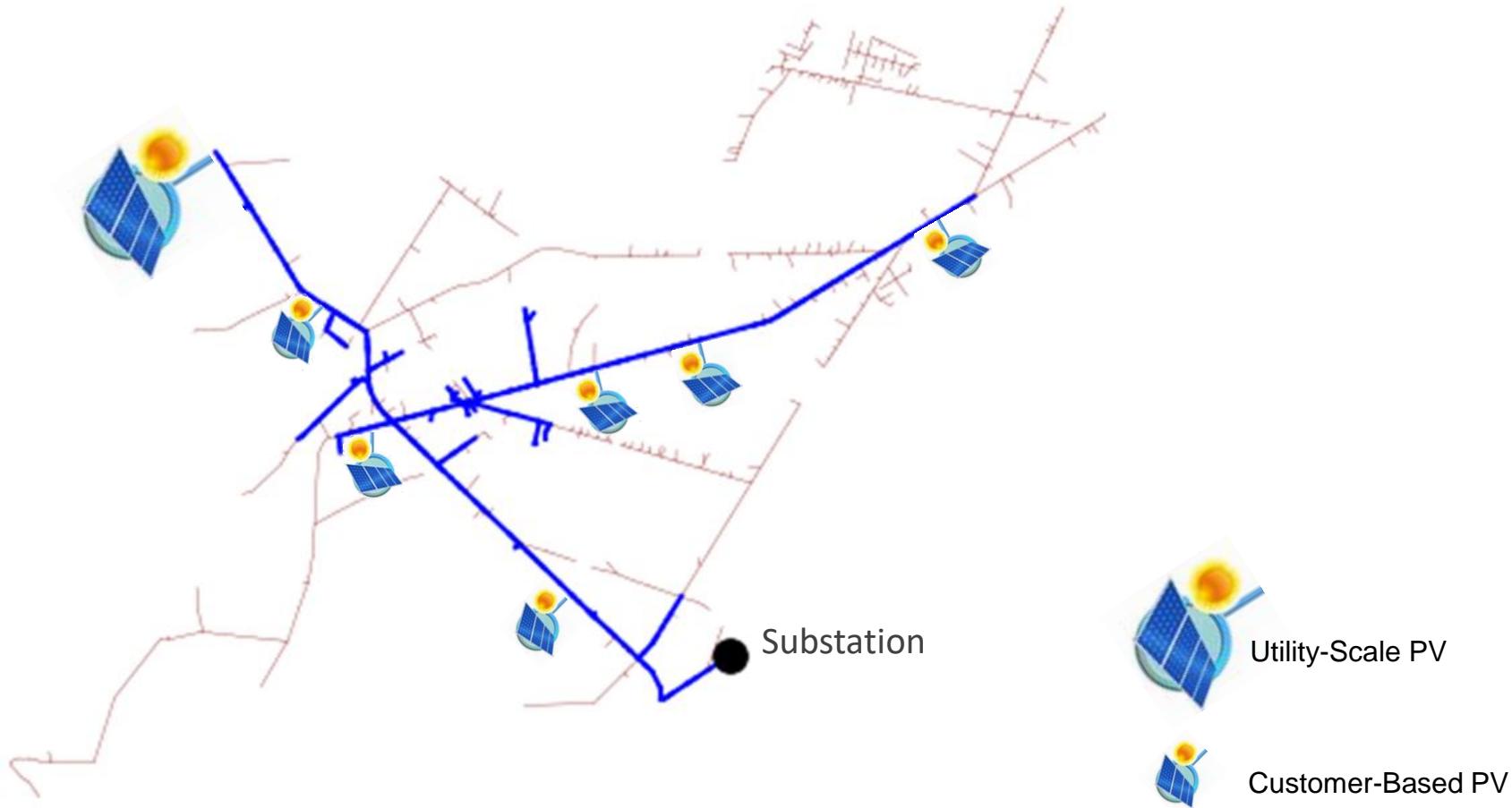
PV systems can cause negative impacts on a distribution system feeder:

- Over/under-voltage conditions,
- Reverse power flow,
- Thermal limit violations,
- Rapid power flow fluctuation,
- Excessive voltage controller actions,
- Etc.



# Hosting capacity

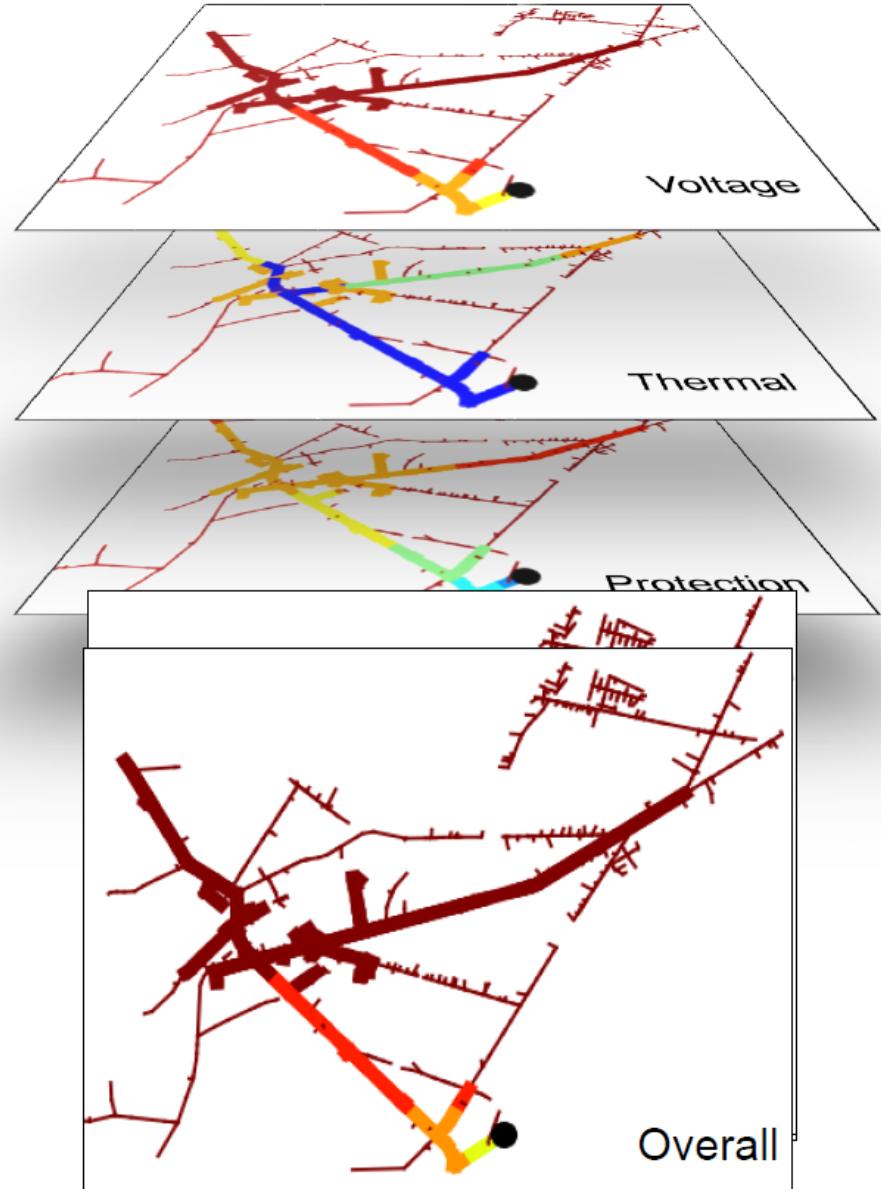
The results from a Hosting Capacity analysis estimates the amount of DER that can be accommodated without adversely impacting power quality or reliability under current configurations and without requiring infrastructure upgrades.



# Hosting Capacity is Issue Dependent

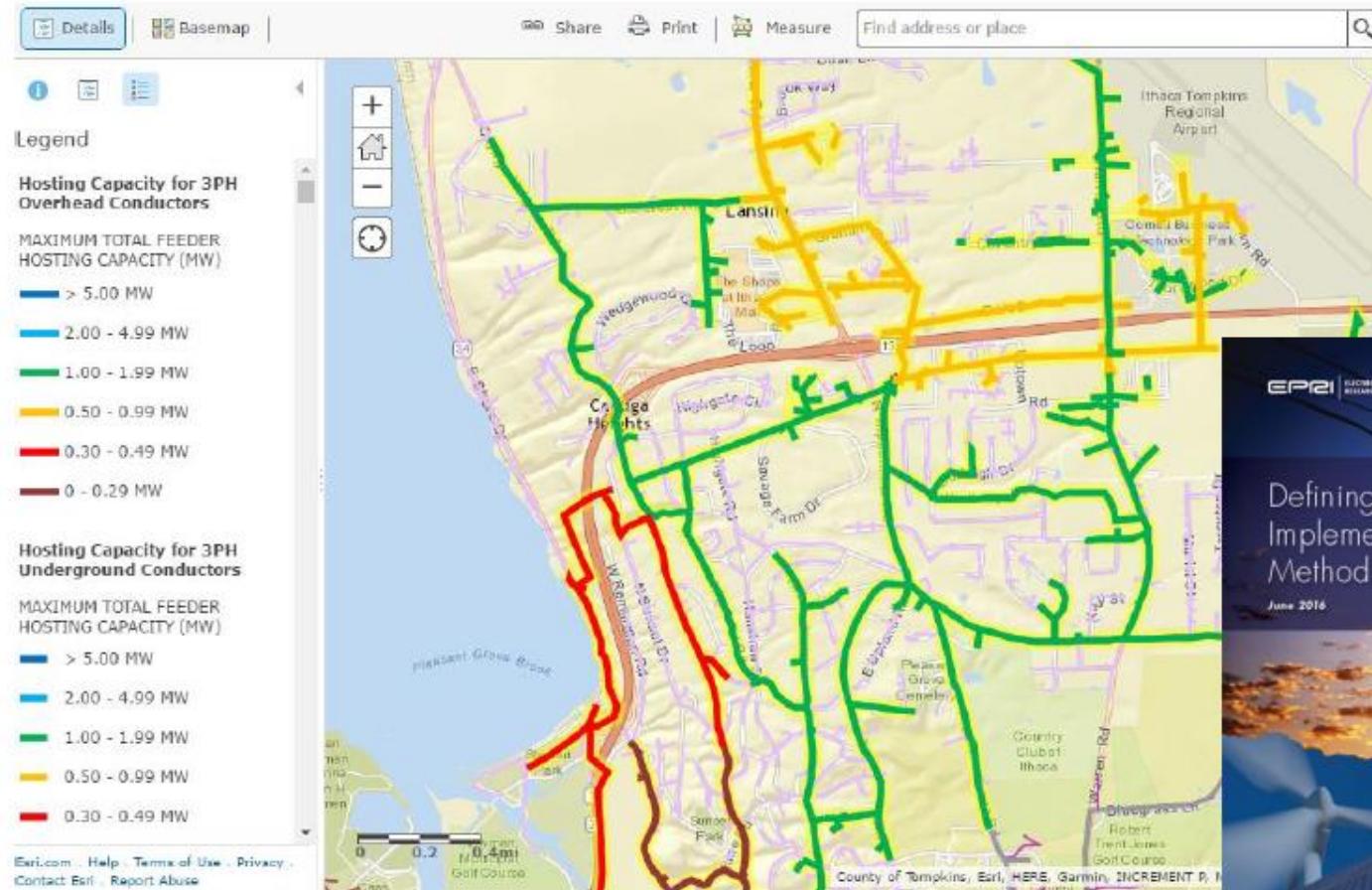
## Impacts Considered

- Voltage
  - Primary overvoltage
  - Primary undervoltage
  - Primary voltage change
  - LTC/Regulator tapping
- Thermal
  - Generating power
  - Demanding power
- Protection
  - Element fault current
  - Breaker relay reduction of reach
  - Sympathetic breaker relay tripping
  - Reverse power flow
  - Unintentional islanding

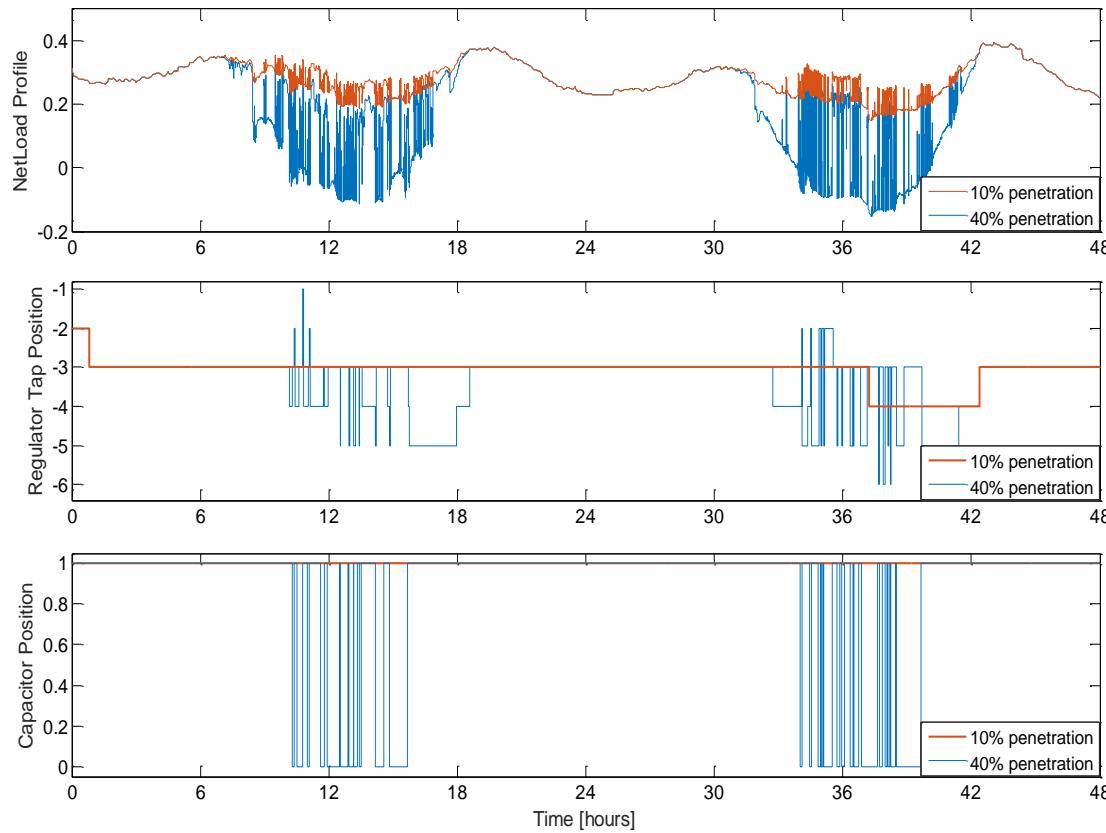
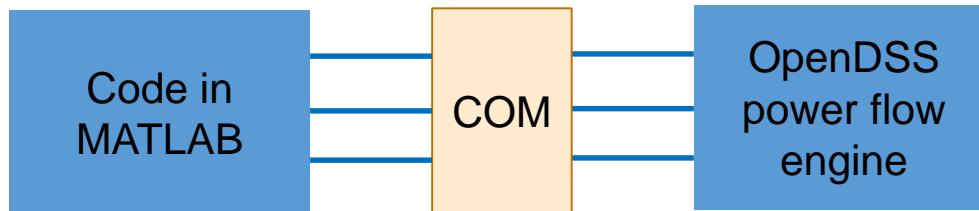


# DRIVE Hosting Capacity Maps Inform DER Developers

<https://www3.dps.ny.gov/W/PSCWeb.nsf>All/6143542BD0775DEC85257FF10056479C?OpenDocument>



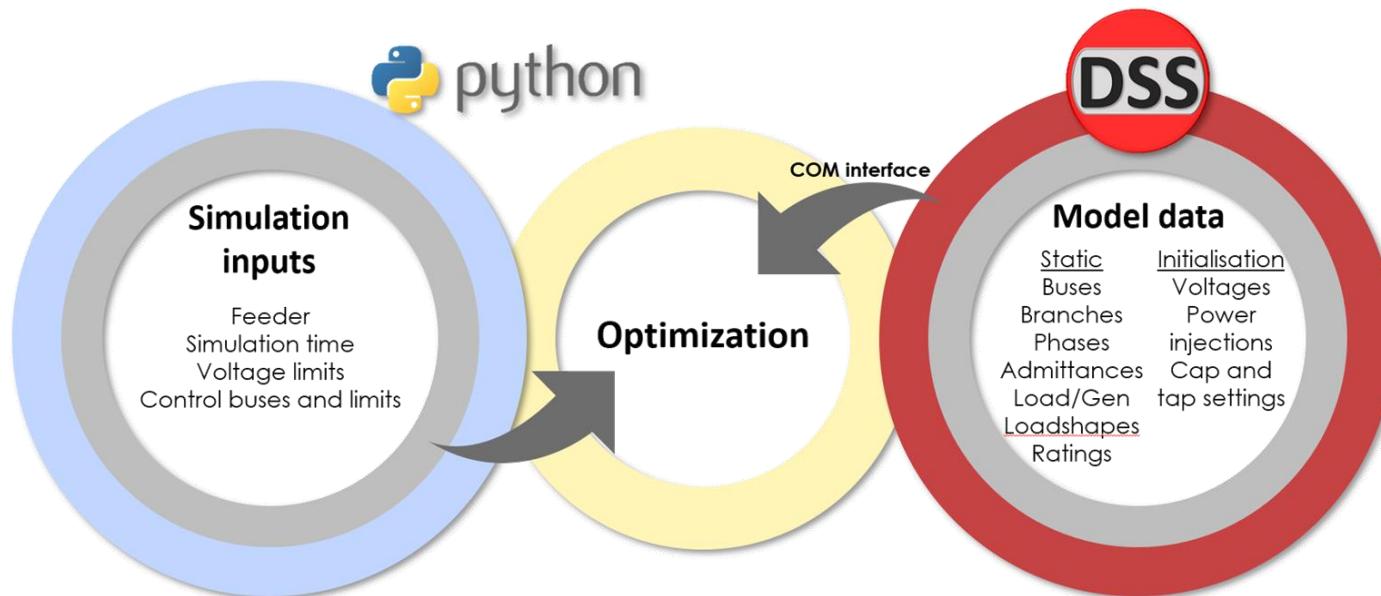
# Impact of DER on Voltage Regulating Equipment



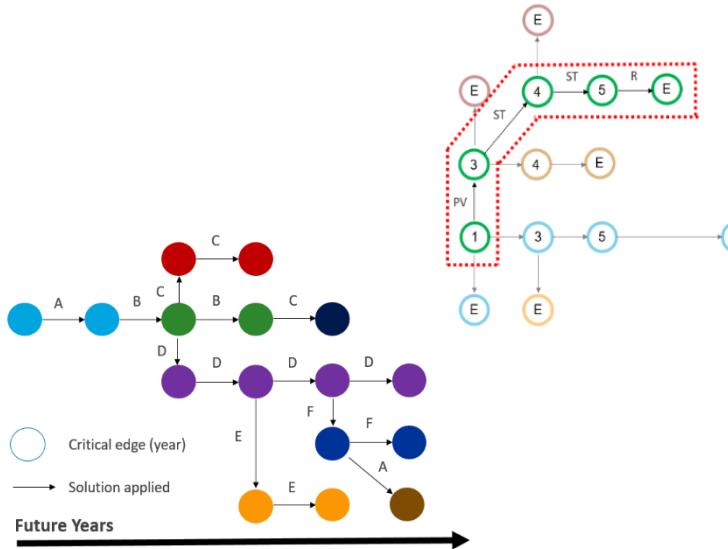
REFERENCE: J. Deboever, 'Fast Interconnection Analysis Of PV Systems Using Vector Quantization'. Georgia Institute of Technology, 2018.

# Distribution OPF

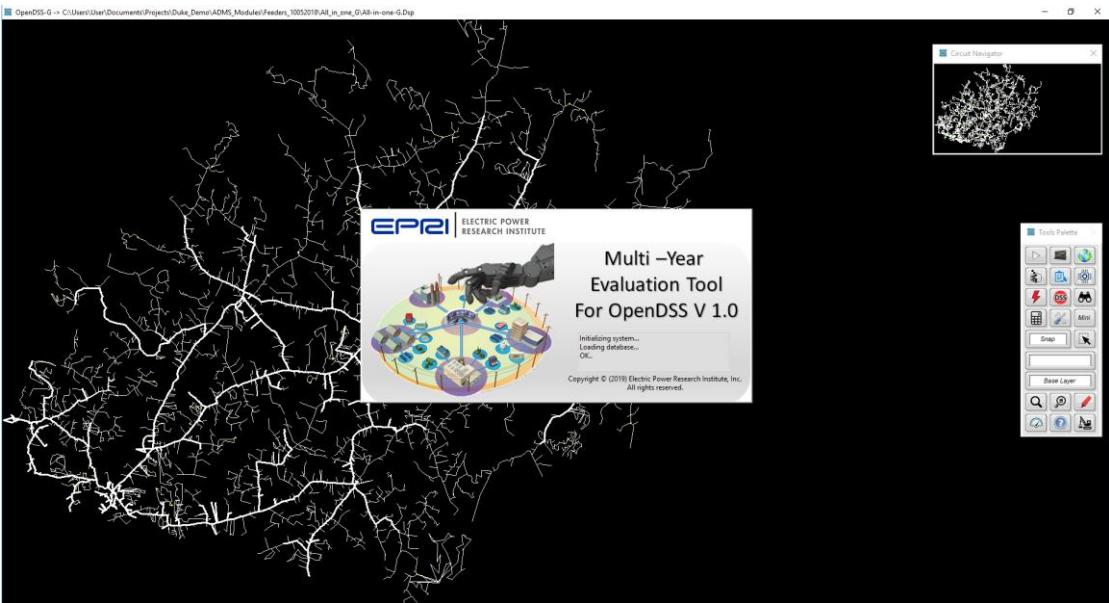
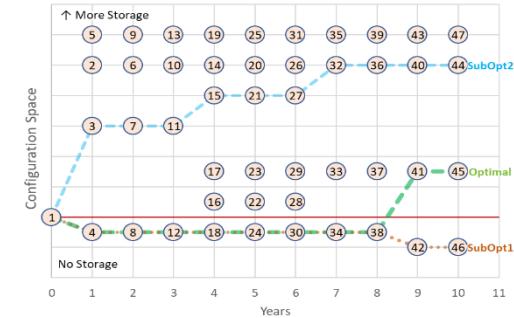
- Three-phase unbalanced optimal power flow
- Python based
- Input data from OpenDSS through COM interface
- Optimization modelled with Pyomo
  - Ipopt solver for problems without integer/binary variables
  - Bonmin solver for problems with integer/binary variables
- Major distribution components modelled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



# Automated Distribution Assessment Platform and Tools



R = re conductor  
LT = Load Transfer  
PV = Photovoltaic  
ST = Storage  
E = end of timeline



Enable distribution planners to effectively account for the dynamics introduced by NWA, more effectively evaluate NWA versus traditional solutions, as well as identify optimal deployment strategies.

# Questions and Answers

The screenshot shows a Cisco Webex Meetings interface. At the top, it says "Cisco Webex Meetings" and "Connected". On the left, there's a sidebar with the EPRI logo and the text "OpenDSS Virtual Training". In the center, there's a large image of a globe with various energy-related icons like power plants and transmission towers, with the text "INTEGRATED GRID & ENERGY SYSTEMS" at the bottom. To the right of the globe is a "Chat" window. A vertical menu on the left has an arrow pointing to a box labeled "Polling, Q&A". The menu items are: Q&A (selected), Lock Event, Invite and Remind, Copy Event Link, and Audio Connection. At the bottom, there's a toolbar with various icons and a "Send to: Everyone" button. The "Enter chat message here:" input field is empty.

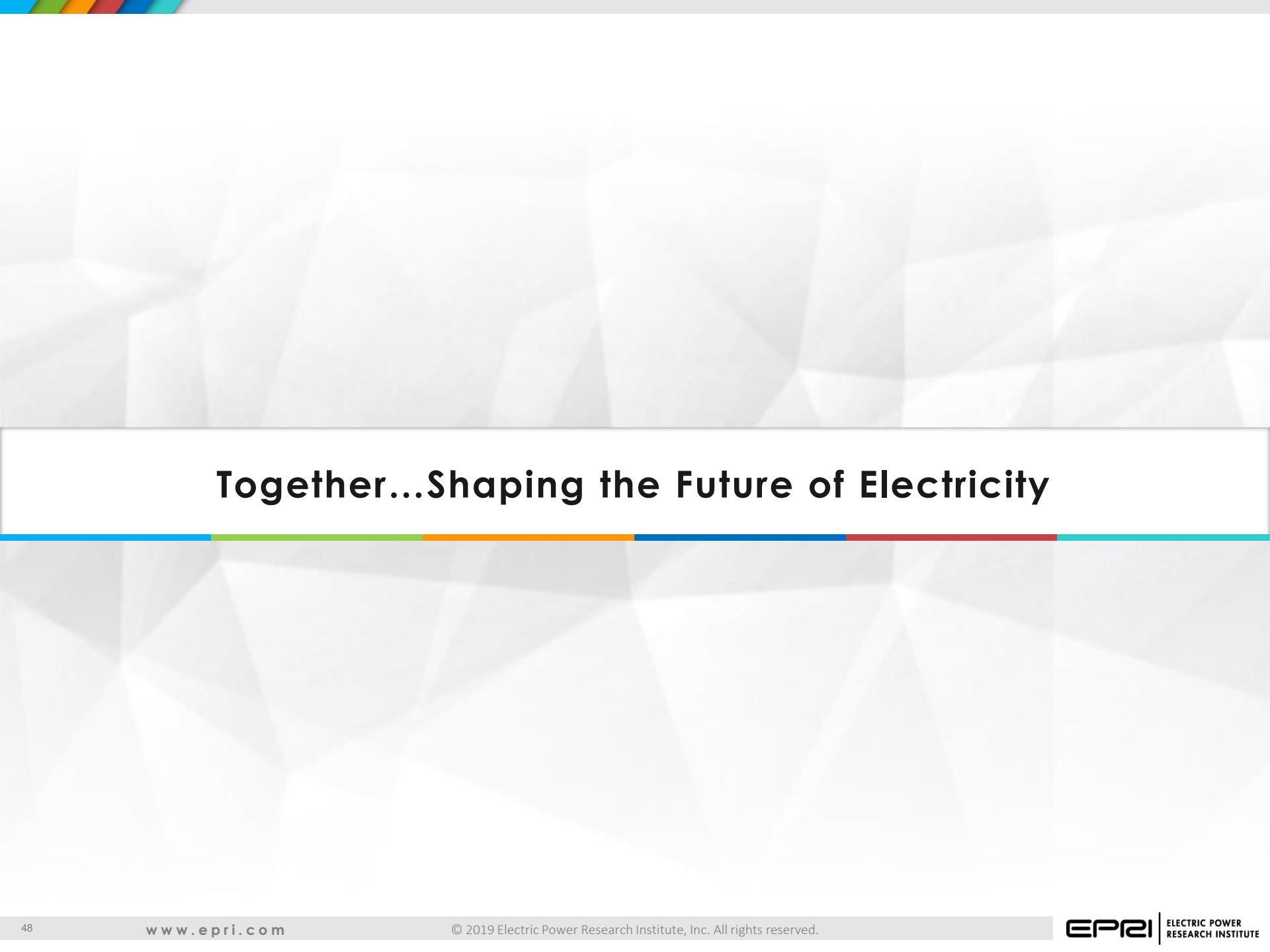
Polling,  
Q&A

# OpenDSS Virtual Training 2020



Date	Time (NY time)	Session Topic
August 24	11:30 am – 12:00 pm	Distribution System Basics
	12:00 pm – 12:30 pm	Intro to OpenDSS
	12:30 pm – 1:00 pm	OpenDSS Basics and Scripting
August 25	11:30 am – 12:00 pm	Intro to OpenDSS-G
	12:00 pm – 12:30 pm	APIs, COM interface, etc.
August 26	11:30 am – 12:30 pm	PVSystem, InvControl, Storage, Storagecontroller
August 27	11:30 am – 12:30 pm	Advanced Topics
	12:30 pm – 1:00 pm	Applying OpenDSS in R&D

Recordings and presentation slides will be made available for free  
at [www.epri.com/OpenDSS](http://www.epri.com/OpenDSS)



# **Together...Shaping the Future of Electricity**

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