Rapid QSTS Simulations for High-Resolution Comprehensive Assessment of Distributed PV

Robert Broderick
Sandia National Labs

SunShot National Laboratory Multiyear Partnership Workshop on Numerical Analysis Algorithms for Distribution Networks

Argonne National Lab

July 21, 2017

Introduction

What is QSTS?

- Quasi-static time series (QSTS) analysis captures time-dependent aspects of power flow, including the interaction between the daily changes in load and PV output and control actions by feeder devices and advanced inverters.
- QSTS is not directly a PV screening or hosting capacity calculation, but a <u>detailed</u> method and tool to <u>directly simulate</u> potential grid impacts for a variety of future scenarios.

Why do we need QSTS?

- PV output is highly variable and the potential interaction with control systems may not be adequately analyzed with traditional snapshot tools
- Many potential impacts, like the duration of time voltage violations and the increase in voltage regulator operations, cannot be accurately analyzed without it.

What is the problem with today's tools?

- Snapshot analyses that only investigate specific time periods can be overly pessimistic about PV impacts because it does not include the geographic and temporal diversity in PV production and load

Simple Comparison of Distribution Simulation Methods

Steady-state (snapshot)

- Follow traditional planning practices
- Require relatively low-resolution input data (multiple time points)
- Are inherently conservative

Quasi-Static Time-Series

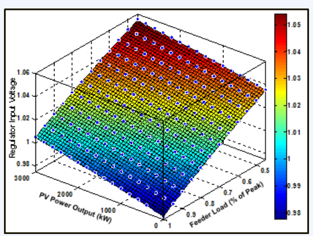
- Require new tools, new experience
- Require high-resolution input data (temporal and spatial)
- Are inherently realistic and more informative
  - Calculate automatic voltage regulation equipment operations, time durations of voltage excursions, etc.

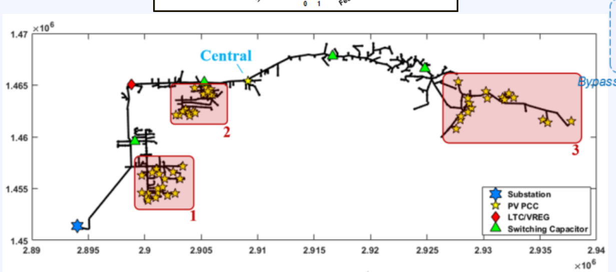
In future hi-pen PV scenarios (or other types of DER) conservative, worst-case analysis, will unnecessarily limit PV integration – thus we need to improve the PV impact study methods

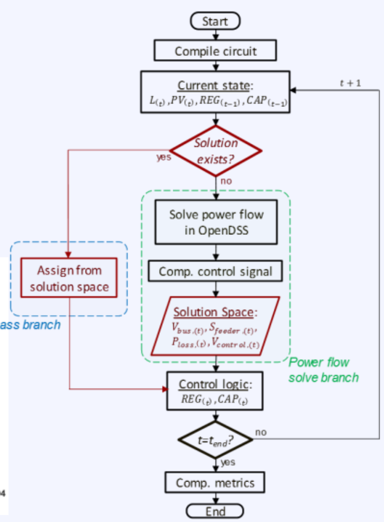
What are we working on?

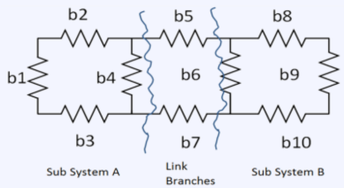
List the SOPO tasks:

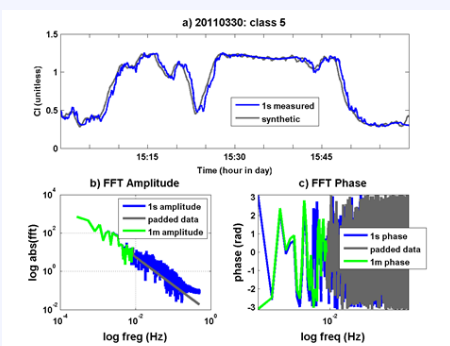
- ✓ Task 1: Fast Time-Series Approximations
- ✓ Task 2: Improved Power Flow Solution Algorithms
- ✓ Task 3: Circuit Reduction
- ✓ Task 4: Parallelization of QSTS-Temporal and Diakoptics
- ✓ Task 5: Implementation with Open DSS and CYME
- ✓ Task 6: High-Resolution Input Data

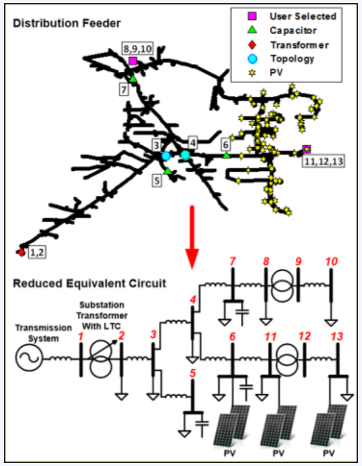












Project Objectives

- Goal: Development new and innovative methods for rapid QSTS Simulations to assess Distributed PV impacts accurately.
- Objective 1:Reduce the computational time (10-120 hours) and complexity of QSTS analysis to achieve year-long time series solutions that can be run in less than 5 minutes at a time step of 1 second.
- Objective 2: Develop high-resolution proxy data sets that will be statistically representative of existing measured load and PV plant data and will provide an accurate representation of PV impacts.
- Objective 3: Improve both the time and accuracy of QSTS analysis in order to make it the industry-preferred PV impact assessment method.

$$\frac{\mathbf{120\ hours}}{\mathbf{10} \times \mathbf{2} \times \mathbf{10} \times \mathbf{7}} = \mathbf{5\ minutes}$$

10	2	10	7
Fast Time-Series Approximation	Improved Power Flow Solution	Circuit Reduction	Parallelization

Summary of Results to Date

Algorithm	Highest Reduction in Computational Time	Notes
Power Flow Optimization	90%	CYME
Circuit Reduction	95%	SNL
Causal Variable Time-Step	93%	NREL
Non-Causal Variable Time-Step	95%	SNL
Quantization	98%	Georgia Tech / SNL
Temporal Parallelization	83%	NREL
Diakoptics	70%	EPRI
Event-Based Simulation	98%	SNL/Georgia Tech
Intelligent Sample Selection with Machine Learning	79%	SNL

Key Accomplishments So Far

- Panel sessions on QSTS at IEEE ISGT and IEEE PES GM
- Published 17 papers! Including collaborative reports on:
  - QSTS data requirements and necessary time-step and simulation duration
  - SAND report on challenges of speeding up QSTS
- 10-15 rapid QSTS algorithms developed. Many demonstrating speed increases of 10-20x
- Temporal parallelization and diakoptics have been fully implemented and integrated in OpenDSS
- CYME improved QSTS speeds up to 10x faster

Questions?

	Simulation Duration		
	1 Day	1 Month	1 Year
Existing Methods	1.6 – 20 minutes	0.8 - 10 hours	10 - 120 hours
Proposed Algorithm Target	3 minutes	4 minutes	5 minutes