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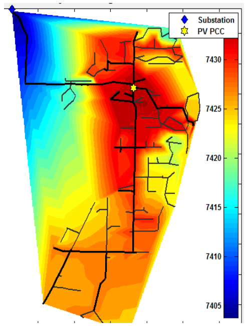

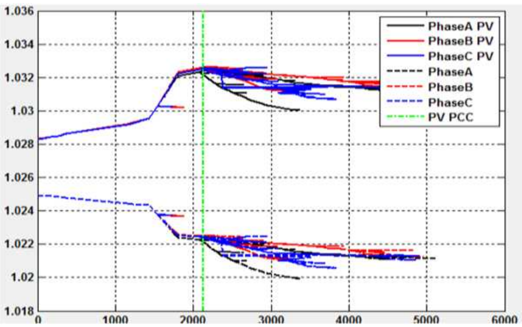

Accelerating Solar Deployment on the Distribution Grid: Rapid QSTS Simulations for comprehensive assessment of distributed PV

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Outline

- Overview of Sandia's DOE funded project to radically speed up Quasi-Static Time-Series (QSTS) Simulations for comprehensive assessment of distributed PV:
  1. Why do we need QSTS?
  2. Goals of the Project
  3. Technical Path Forward

Time Series Simulations

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 detailed tool to directly simulate grid impacts for a variety of future scenarios.

Why do we need QSTS?

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

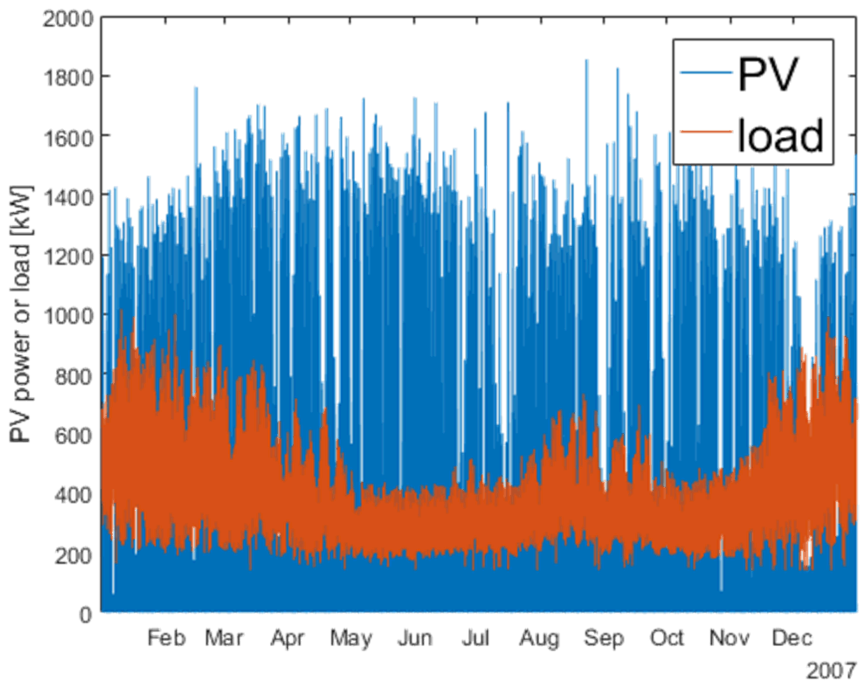
What is the problem with today's methods?

- Snapshot analyses that only investigates 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
- QSTS simulation in existing software is too slow for the needed simulations (year-long) at the high time resolution needed to capture solar variability (time steps less than 15 seconds)

Time Series Simulations

What is the next step?

- Utilities and developers need high speed modeling tools and access to high resolution data to accurately determine the impact of high penetrations of PV and other DER on the distribution system

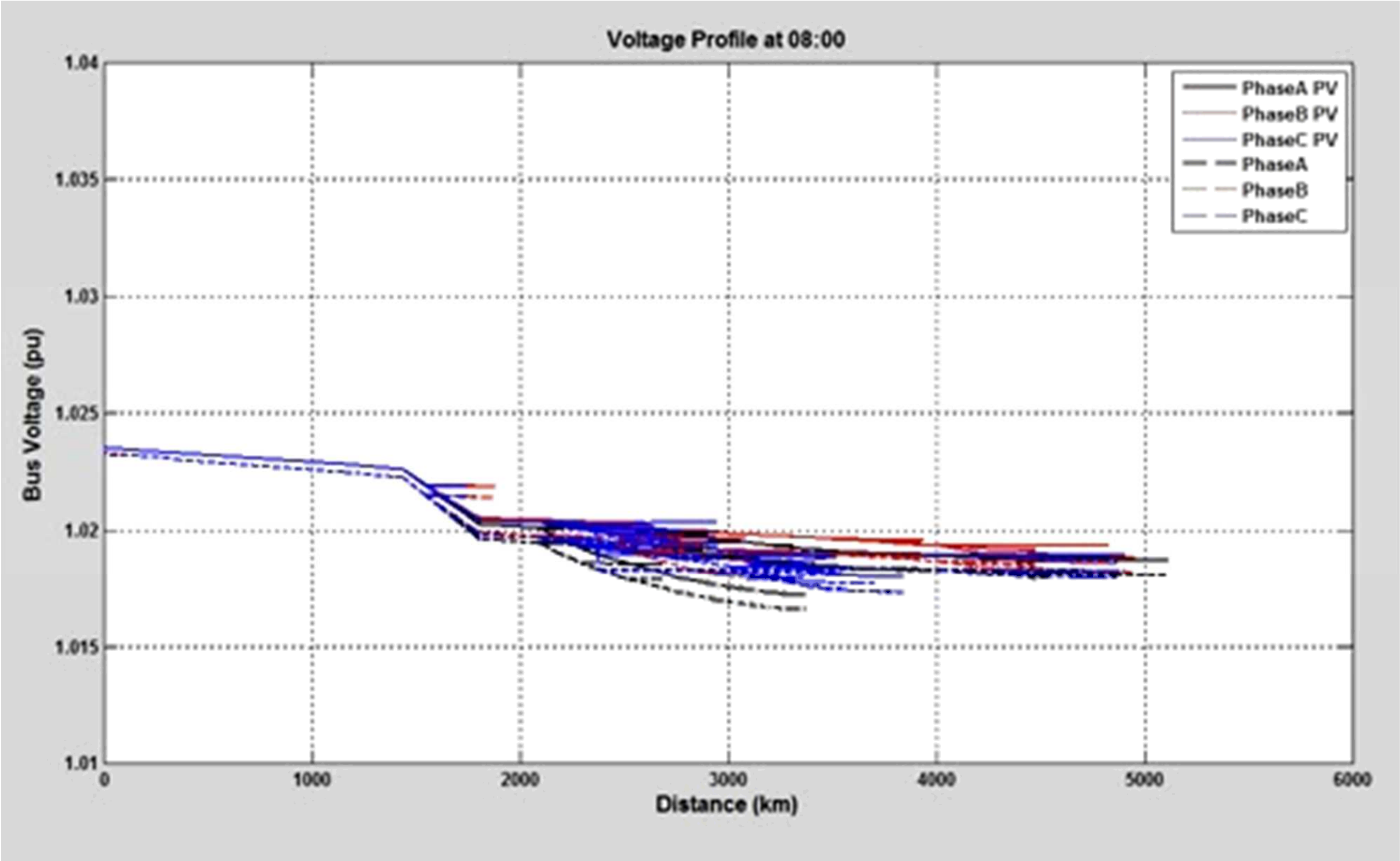


Impact Analysis

- High penetrations of PV can affect the distribution feeder equipment and the operation of the system
  1. Designed for radial flow in one direction from the substation
  2. Designed for aggregated loads with little short-term variability

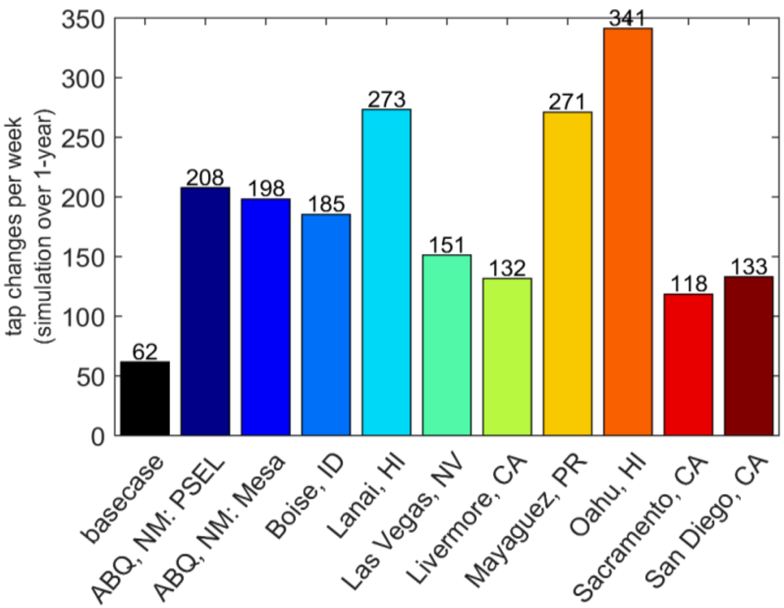
- Distribution system impacts
  - Voltage Regulation Device Operations
  - Steady State Voltage
  - Voltage Flicker

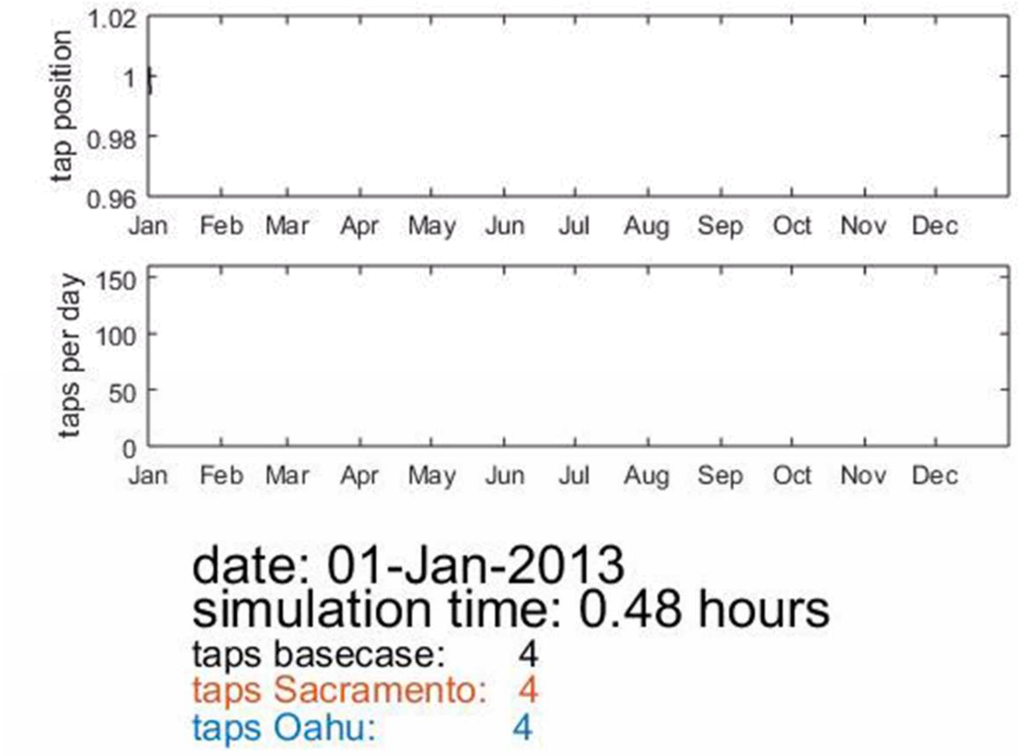
Impact Analysis



Time Series Results

- QSTS simulates the number of tap changes on voltage regulators
- Results depend the input data and seasonal variations
- QSTS simulations present a significant computational burden





Goals of QSTS Project

- Existing QSTS algorithms can take anywhere from 10 to 120 hours to perform a high resolution 1-year simulation at 1-second resolution.
- During the course of the project, algorithms will be developed to dramatically reduce the computational time to <u>less than 5 minutes</u> for a year-long high-resolution time-series simulation, allowing QSTS to be incorporated into the utility interconnection process and decision support tools.
- We are going to <u>***transform***</u> how the industry performs impact analyses by replacing old fashion static tools with new <u>fast and accurate</u> tools that are focused on solving the time dependent problems of PV in the modern distribution system.

Project Team

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DOE Funds: $4,000,000 for 36 months
Cost-Share Funding (CYME & EPRI): $810,000

Proposed Solution – Technical Approach

- Task 1 – Fast Time-Series Approximations
- Task 2 – Improved Power Flow Solution Algorithms
- Task 3 – Circuit Reduction
- Task 4 – Parallelization of QSTS Analysis
- Task 5 – Implementation of Accelerated QSTS
- Task 6 – High-Resolution Input Data.

Target Performance Level

- Year-long high-resolution (1 Sec) time-series solutions that can be run in less than 5 minutes for utility decision support systems.
- The ratio of relative speed improvements between algorithm improvements and parallelism is part of the R&D question, but hypothetically we could do it using:

$$\frac{\mathbf{120\ hours}}{\underset{\text{Fast Time-Series Approximation}}{\mathbf{10}} \times \underset{\text{Improved Power Flow Solution}}{\mathbf{2}} \times \underset{\text{Circuit Reduction}}{\mathbf{10}} \times \underset{\text{Parallelization}}{\mathbf{7}}} = \mathbf{5\ minutes}$$

Computation times for 1-second resolution QSTS

	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

Preliminary Results

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- Project began December 1st 2015. Project status meeting completed 5/4/16 at IEEE T&D.

	Preliminary Results
Task 1 Fast Time-Series Approximations	~6 different approaches are being investigated
Task 2 Improved Power Flow Solution Algorithms	~60% reduction in power flow solve time using methods that reuse solution from previous time step
Task 3 Circuit Reduction	Circuit Reduction methods showing great promise to achieve at least a 90% reduction in complexity
Task 4 Parallelization of QSTS	Diakoptics Methodology under development
Task 5 Implementation	Begins in Year 2
Task 6 High-Resolution Input Data	Solar irradiance algorithm is being evaluated

Circuit Reduction on Range of Feeders

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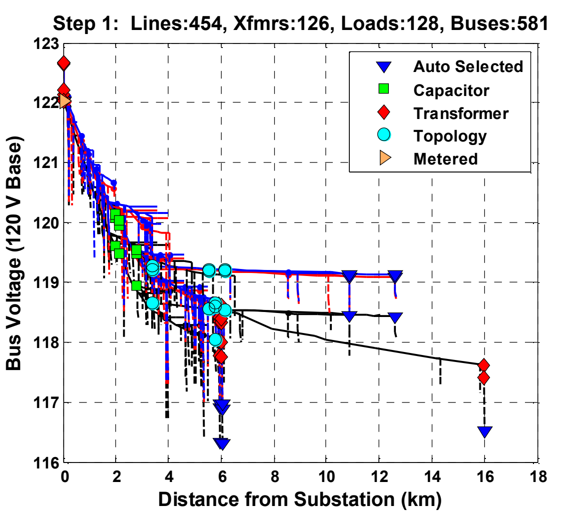
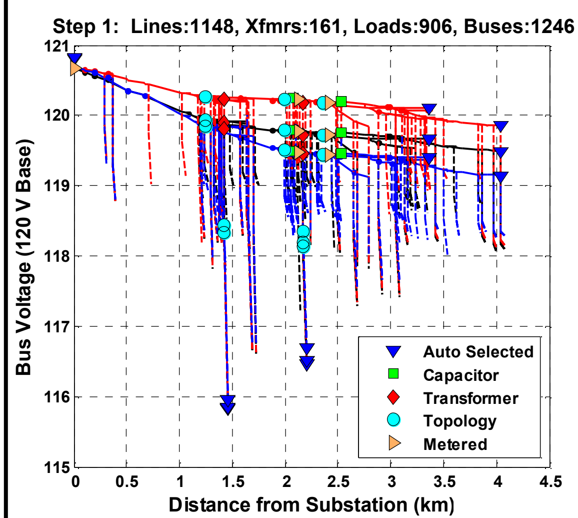
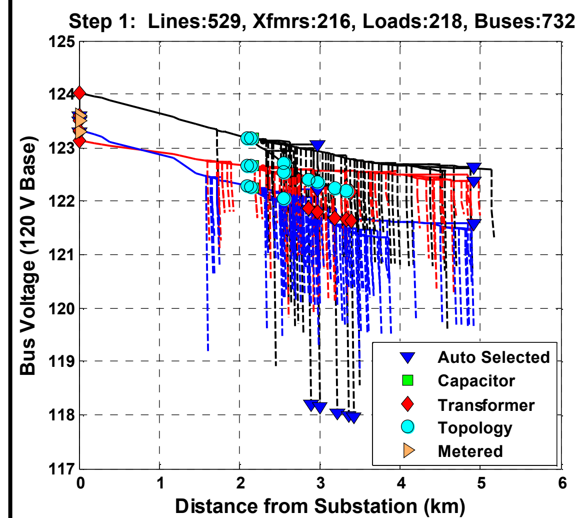
	Feeder UT11 96% Reduction <0.01% Error	Feeder Ckt 7 98% Reduction <0.02% Error	Feeder UQ11 97% Reduction <0.02% Error
Full	see chart 1	see chart 2	see chart 3
Reduced	see chart 4	see chart 5	see chart 6

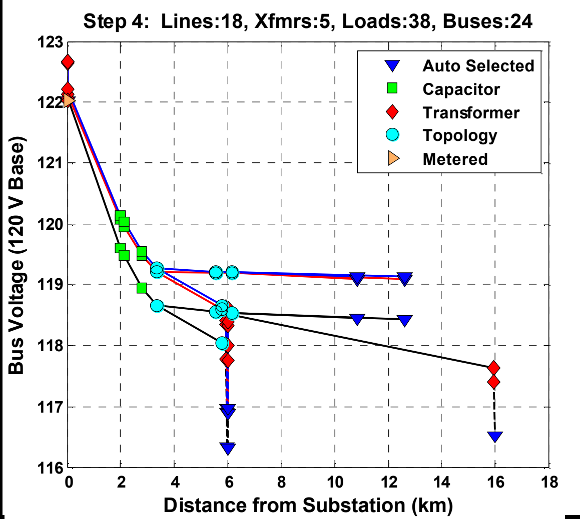
Full

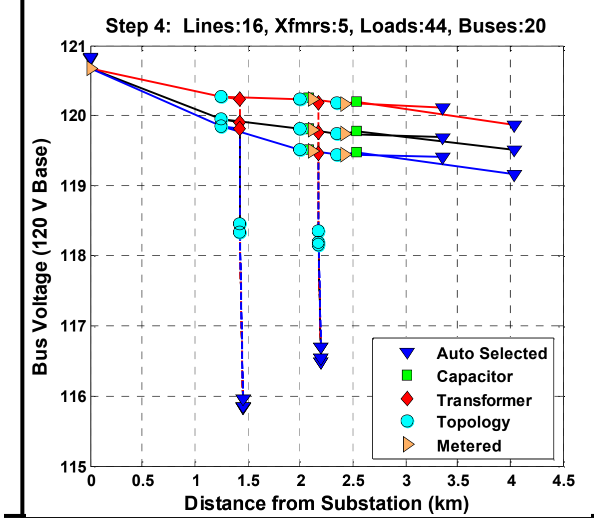


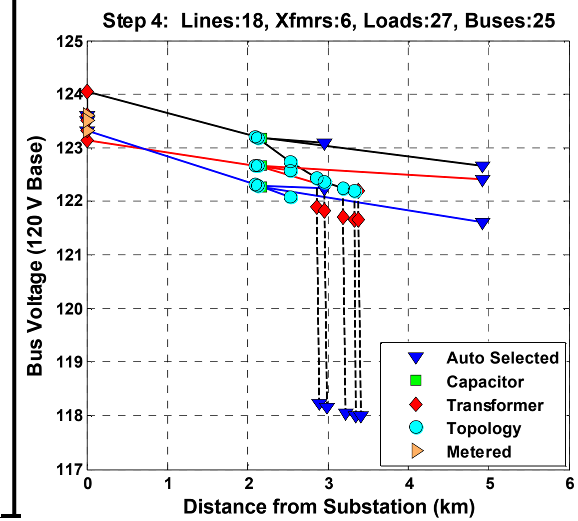




Reduced







QUESTIONS?

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