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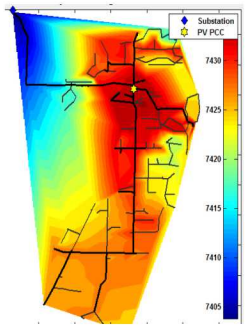

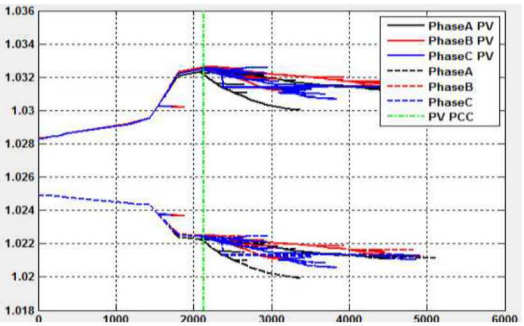

Visualization Methods for Quasi-Static Time-Series (QSTS) Simulations with High PV Penetration

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Introduction

- Distribution system analysis with high penetrations of distributed PV requires **quasi-static time-series (QSTS)** analysis to capture the time-varying and time-dependent aspects of the system
- QSTS simulations solve a series of sequential steady-state power flow solutions, where the converged state of each iteration is used as the beginning state of the next
- Rapid QSTS algorithms have been developed to reduce the computational time while maintaining accuracy

Background

- Each power flow generates potentially **tens of thousands** of data points, depending on the size of the circuit:
  - Node and bus voltages
  - Line and transformer loading
  - Active and reactive power injections (PV, energy storage, or other DER)
  - Controller states (voltage regulator tap position or switching capacitor state)
  - Active and reactive power loss

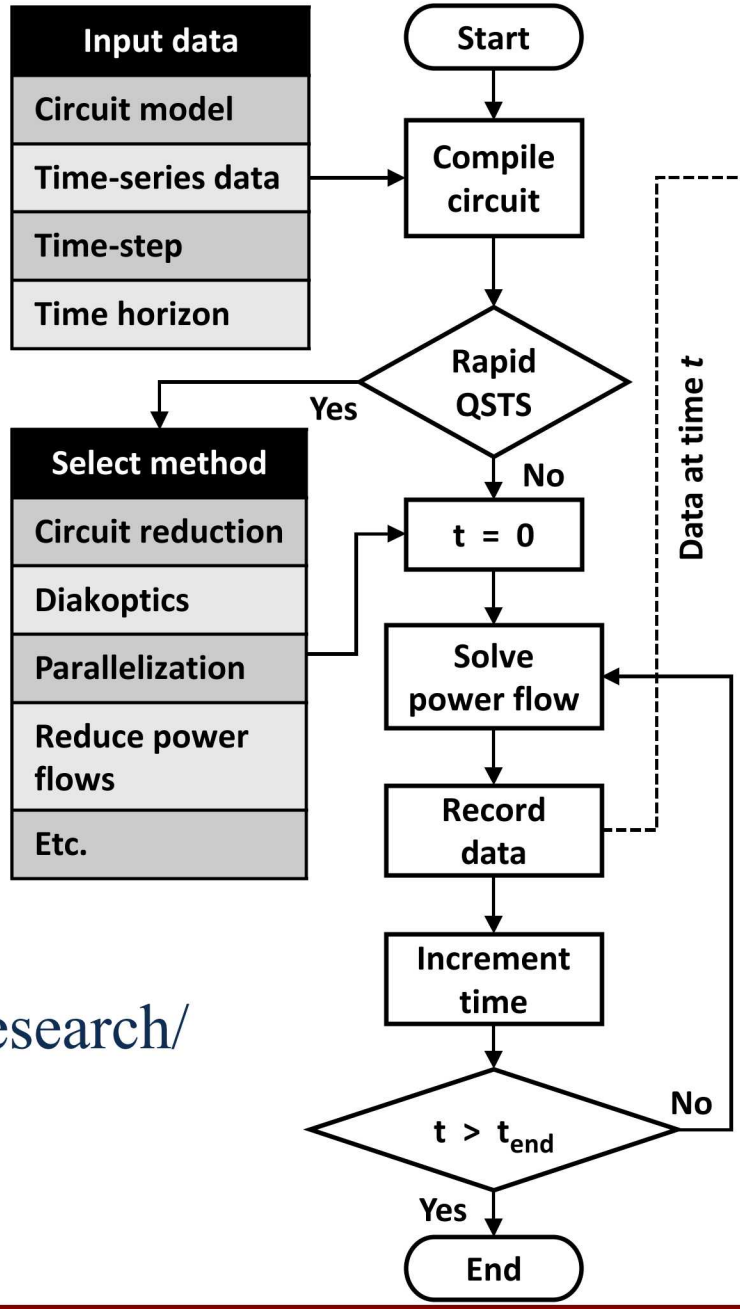
- A single yearlong QSTS simulation solves **millions** of power flows

- Visualization methods are needed to facilitate analysis of QSTS results

Background

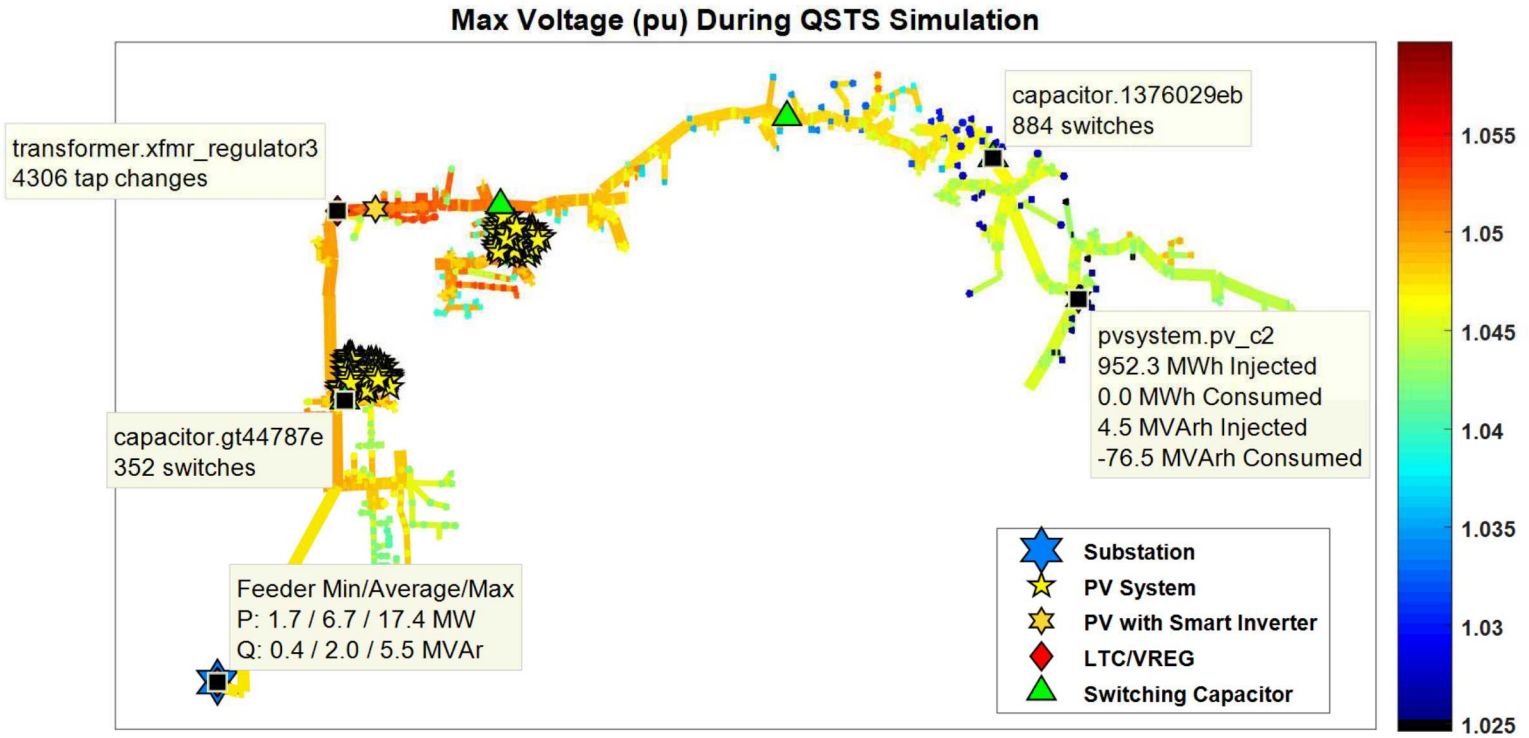
- Visualization methods can handle results from QSTS simulations using any algorithm
- User can choose what types of data to record
- MATLAB code and other QSTS resources will be publicly available:

https://pvpmc.sandia.gov/pv-research/quasi-static-time-series-qsts/



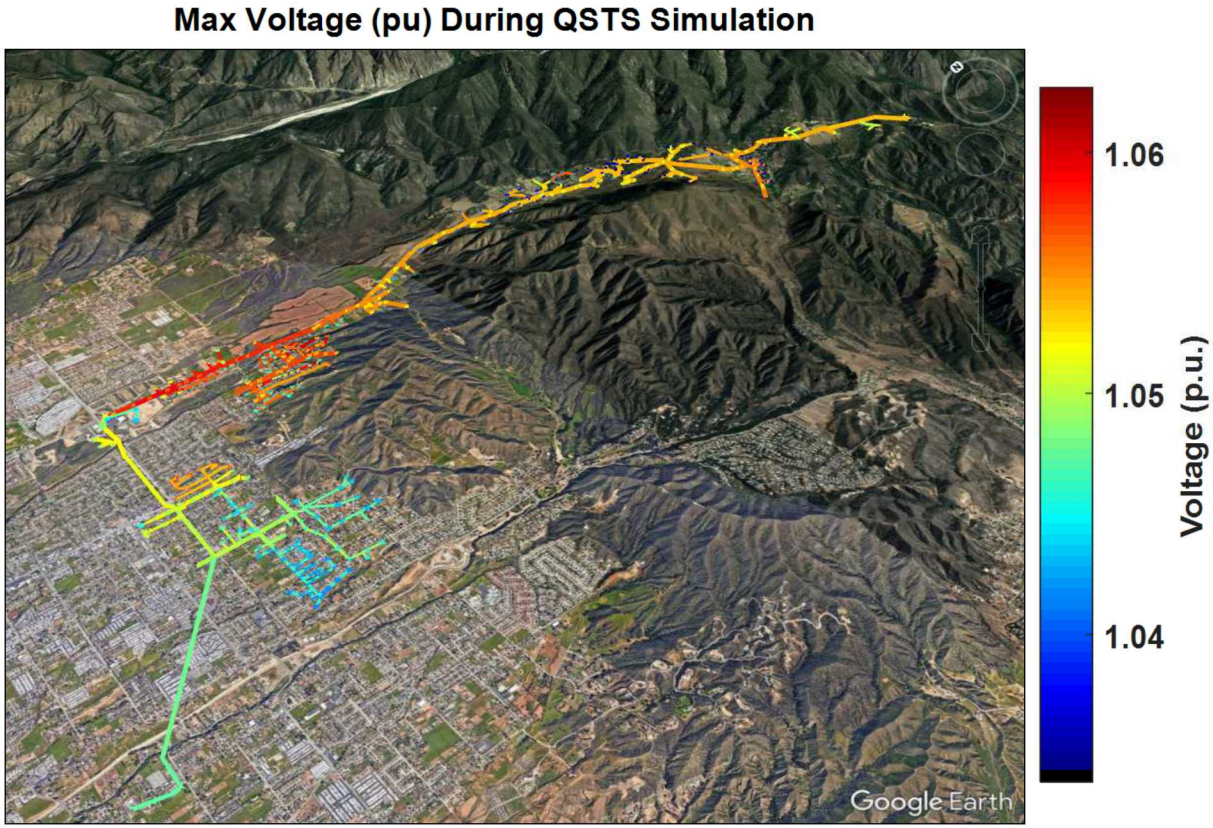
Circuit Plots

- Conventional circuit plots used in snapshot analyses can be infused with QSTS data
- Lines are colored based on QSTS results (e.g. by voltage or loading)
- Elements are clickable, revealing additional information



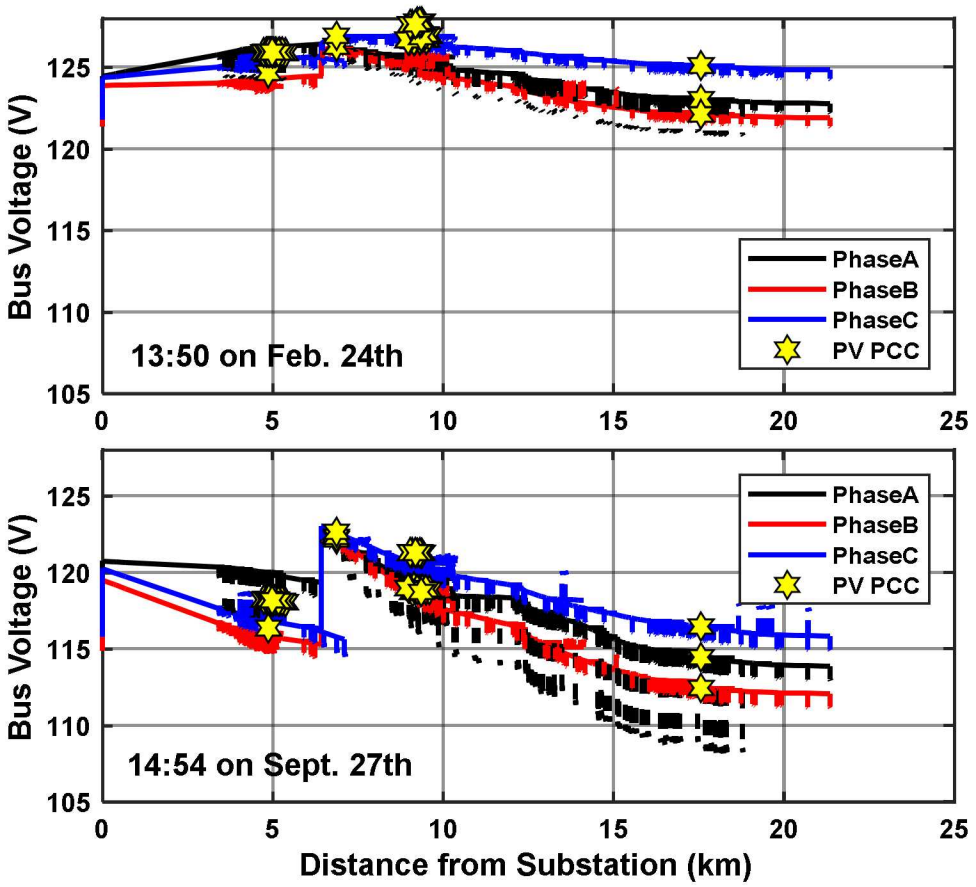
Circuit Plots

- If the model contains actual coordinates, the same type of colored circuit plots can be exported to Google Earth

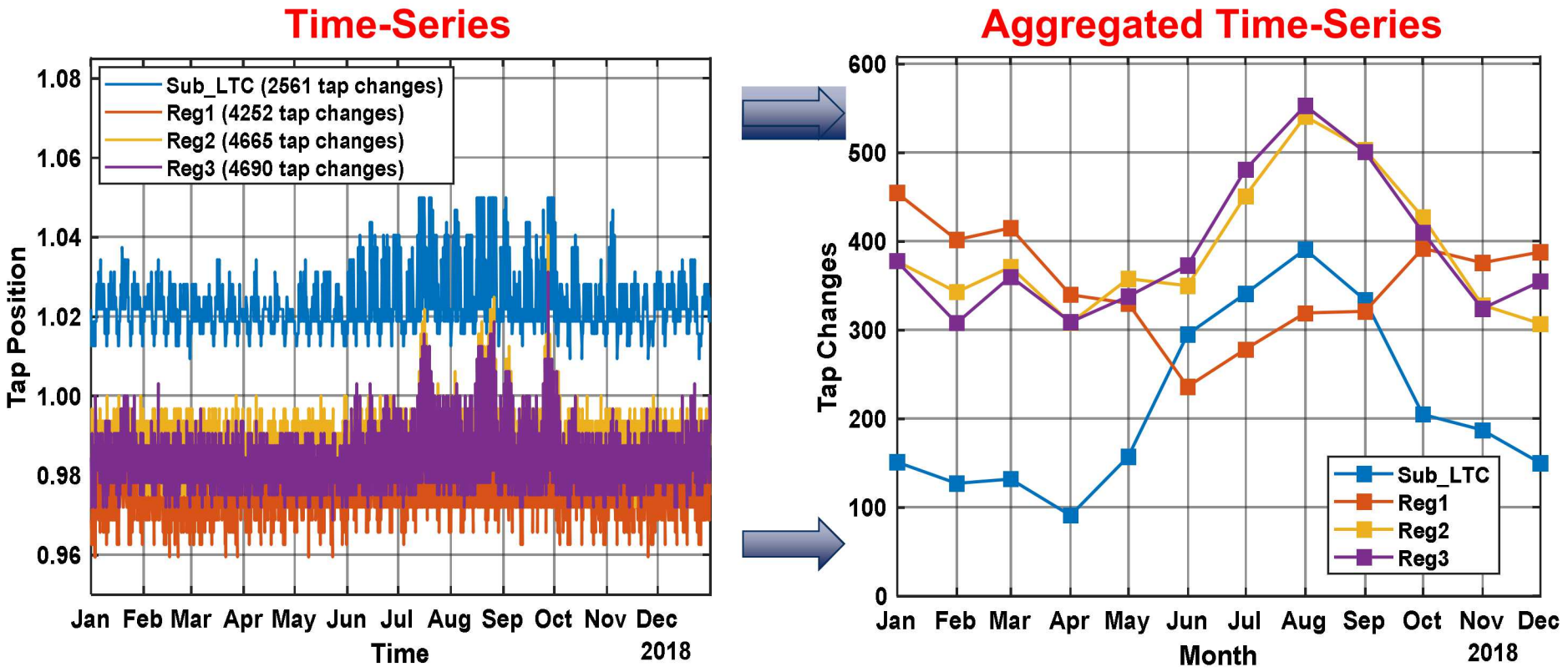


Voltage Profiles Along a Feeder

- Similar to voltage profile plots from snapshot analyses, where voltage is plotted as a function of distance from the substation
- QSTS results allow the user to "rewind" to a specific point in time, e.g. to times of extreme condition on the feeder



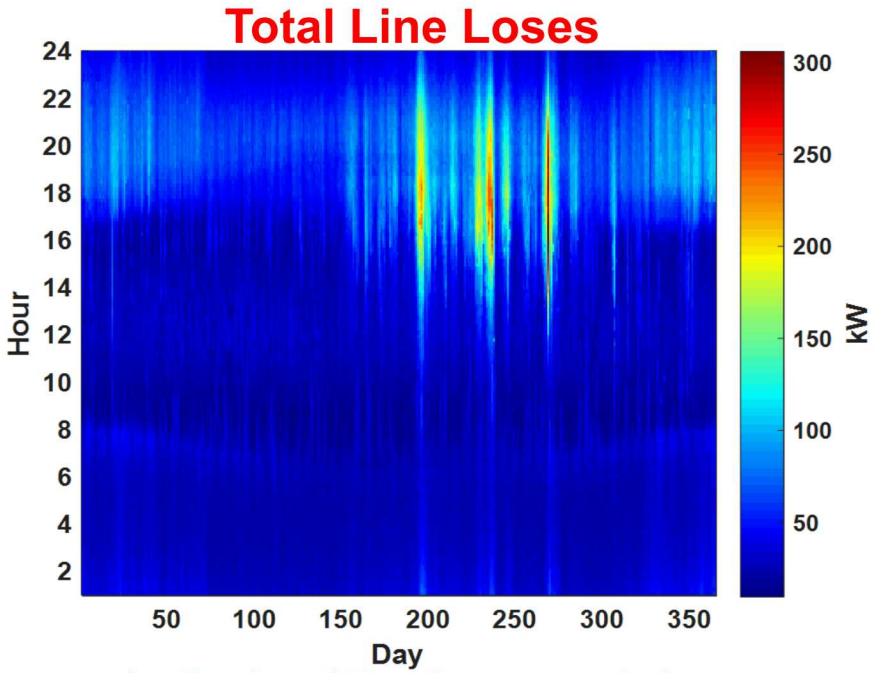
Aggregated Time-Series

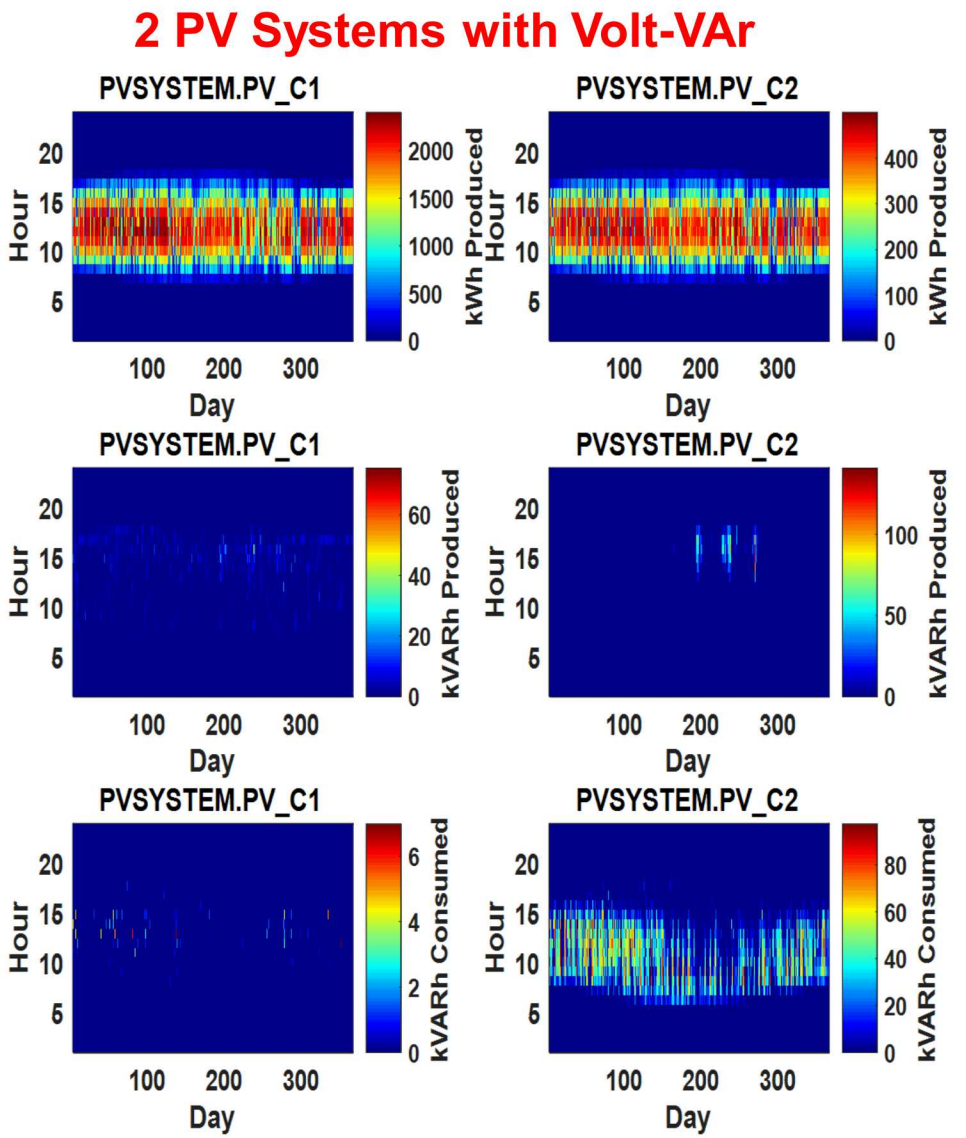


- Aggregating the results can help to identify underlying trends

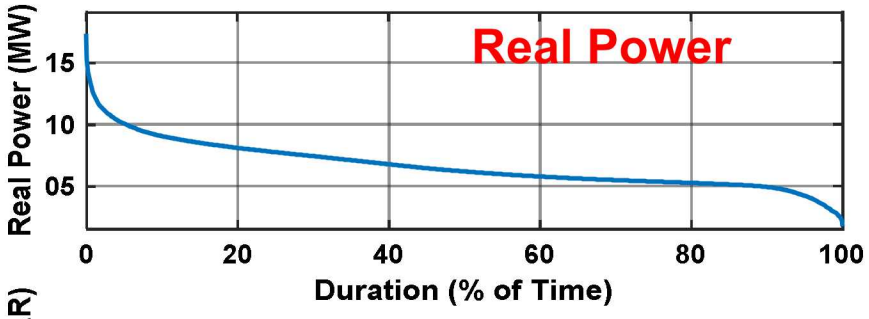
Raster Plots

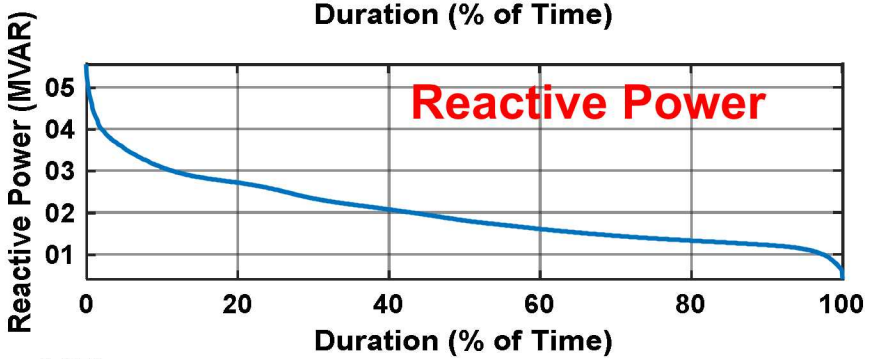
- Color is used to represent the variable's magnitude
- Pixel size can be adjusted based on desired level of detail

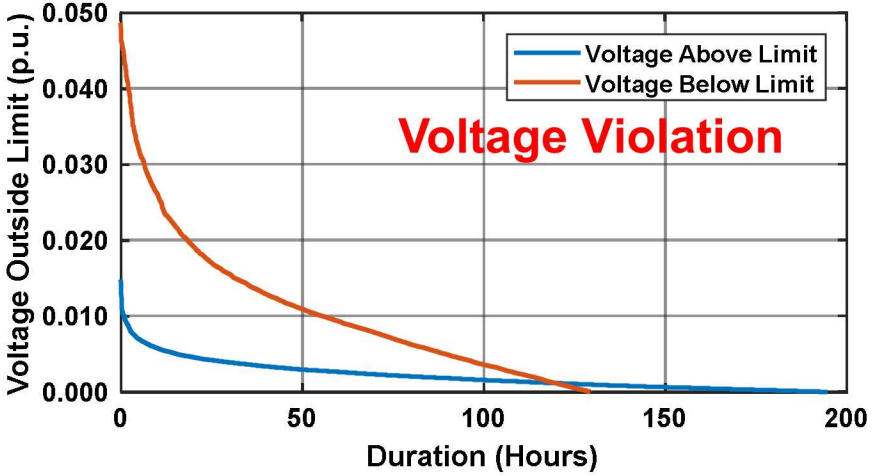


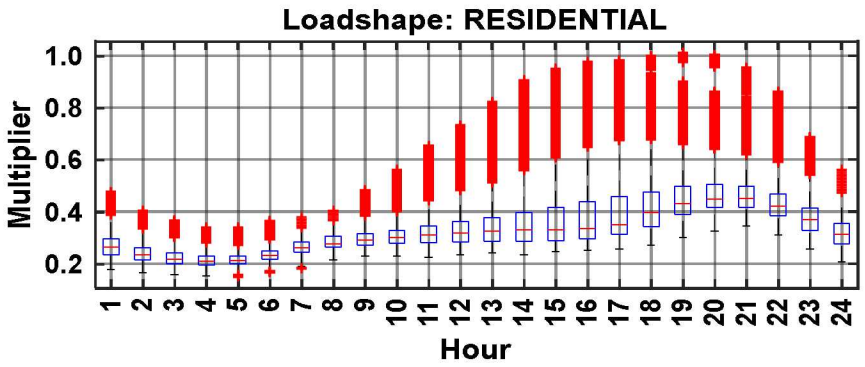


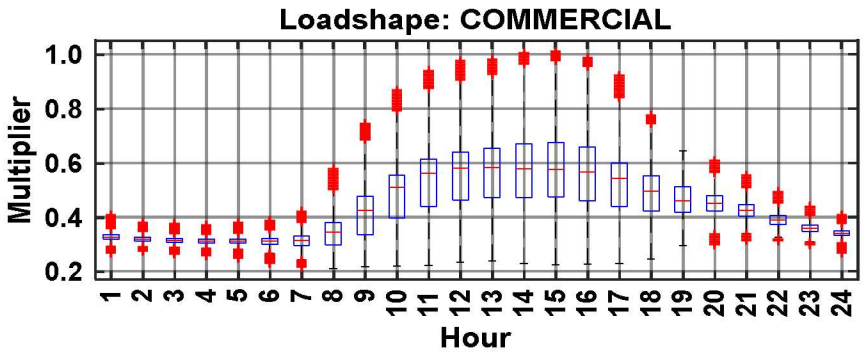
Statistical Distributions

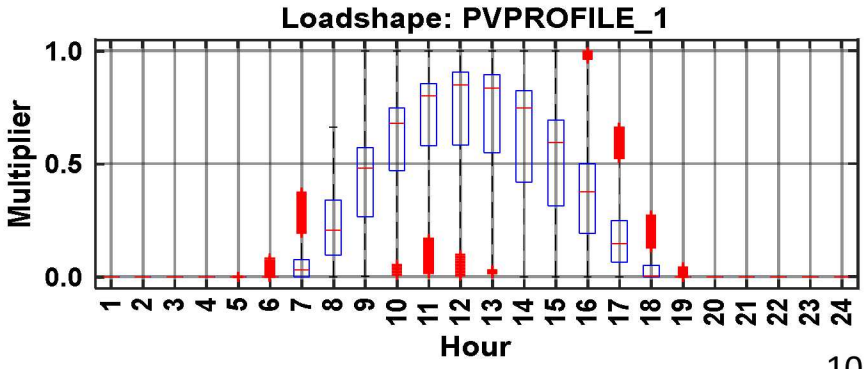






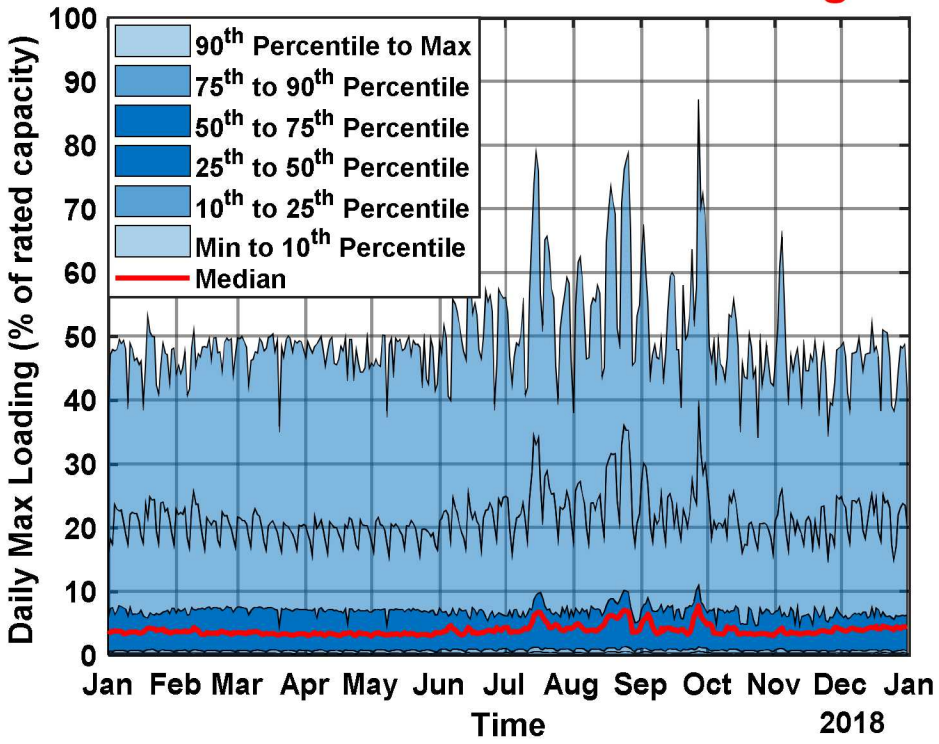






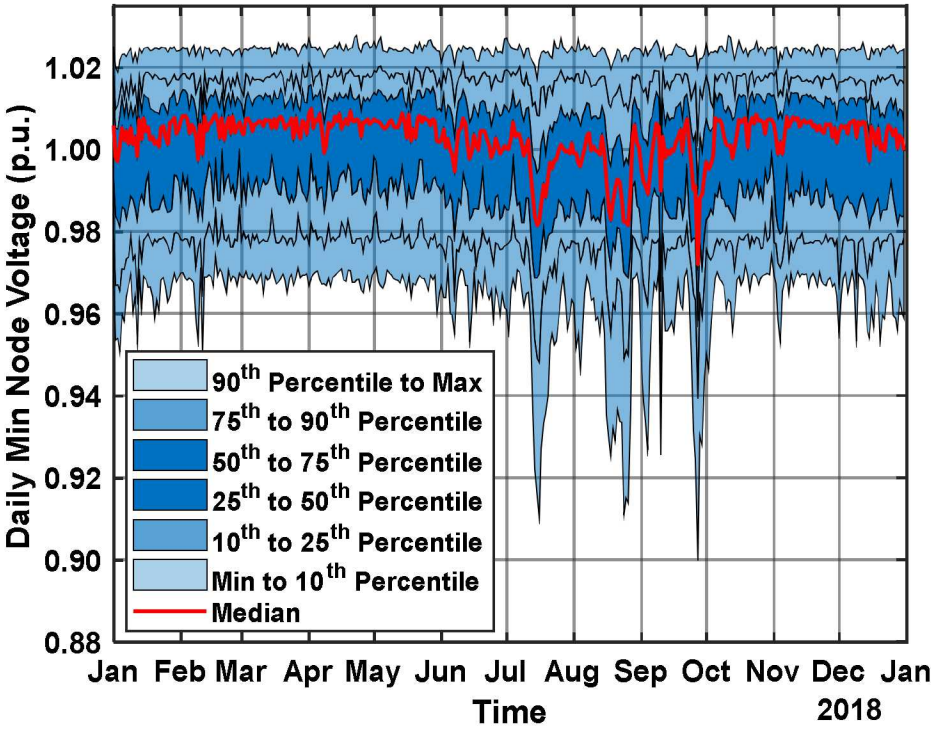
Statistical Distributions

Line and Transformer Loading



(2,970 Elements)

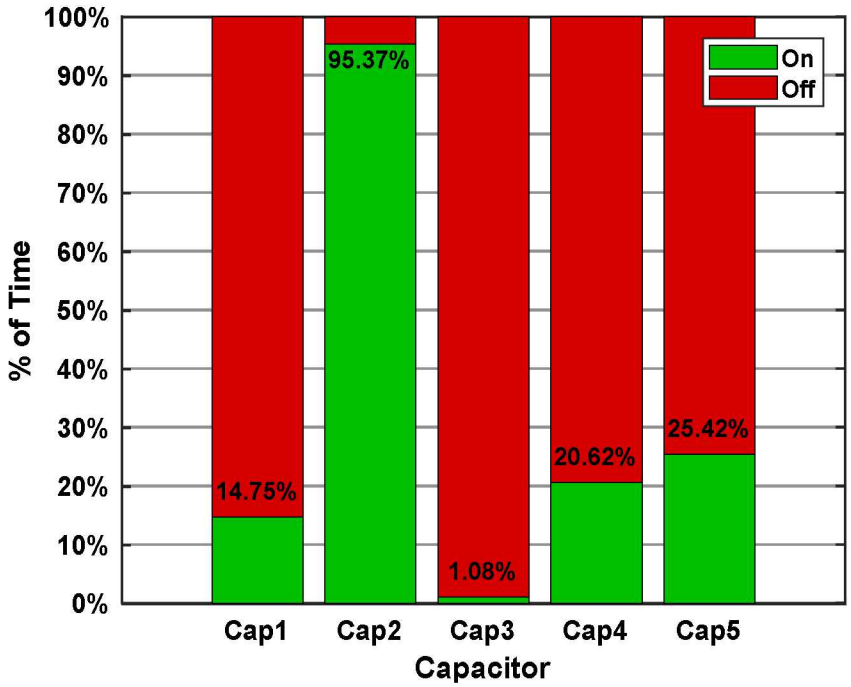
Node Voltages

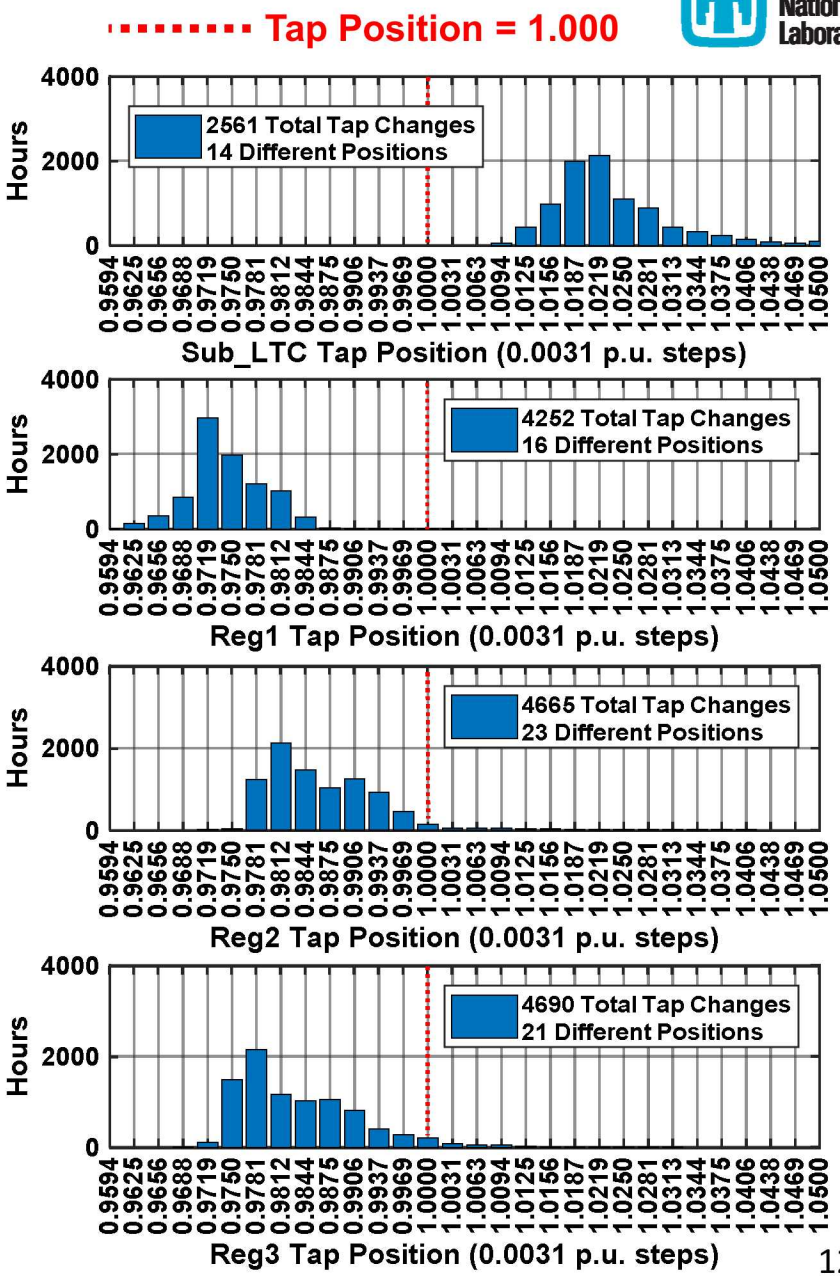


(5,469 Nodes)

Controller States

- Controllable devices like step-voltage regulators and switching capacitors tend to operate more frequently in the presence of increase variability





Conclusions

- QSTS simulation will be a critical aspect of future power system analysis with high penetration of renewable energy and increasing number of smart grid controls
- This paper proposes a number of visualization methods that leverage the detailed time-series data unique to QSTS simulations in a way that facilitates the analysis of modern distribution circuits
- The proposed visualization methods are coded to handle results generated from any standard or rapid QSTS simulation
- Code is open-source and will be publicly available, along with other QSTS resources at:

https://pvpmc.sandia.gov/pv-research/quasi-static-time-series-qsts/

Link is available in the paper

QUESTIONS?

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Link is available in the paper