Enabling Higher-Fidelity DER Interconnection Planning – the Rapid QSTS Project

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

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Motivation for Rapid QSTS

- Accurate modelling of high penetration PV requires understanding the time varying impacts of variable generation on the distribution system
- QSTS also plays a major role in analysis and planning of many other smart grid technologies, control schemes, ADMS function, energy storage, etc.

Steady-state (snapshot)

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

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

Quasi-Static Time-Series

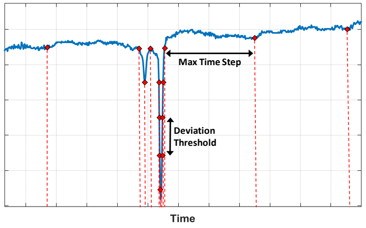
- Require new tools, new experience
- Require high-resolution input data (temporal and spatial)
- Are inherently realistic and more informative
  - Calculate automatic voltage regulation equipment operations, time durations of voltage excursions, etc.

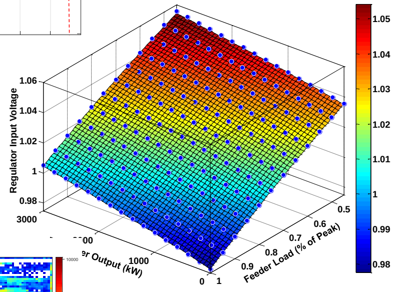
Rapid QSTS Objectives

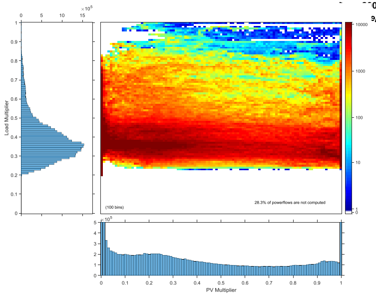
- Accelerate QSTS simulation capabilities through use of new and **innovative** methods for advanced quasi-static time-series analysis
- Reduce the current QSTS analysis computational time (**10-120 hours**) that is not possible for utilities in order to make QSTS the industry preferred PV impact assessment method (**target – 5 minute runtime for 1 year analysis at 1 second resolution**)
  - Develop rapid QSTS algorithms that significantly reduce computation time
  - Maintain high accuracy across variety of PV impact metrics
  - Be scalable to different feeders, data sets, and technologies
- Develop **high-resolution proxy data** sets that will be **statistically representative** of existing measured load and PV plant data for an accurate representation of PV impacts

Innovation in Time-Series Approximation

- Variable Time-Step
  - Reduce the computational burden by adjusting the QSTS time-step to solve fewer load flows, skipping forward to time points of interest
- Event-Based Simulation
  - Detect discrete system events using voltage sensitivities and jump from event to the next
- Vector Quantization
  - Take advantage of repeated power flow computations using a quantized lookup table to bypass the power flow solver





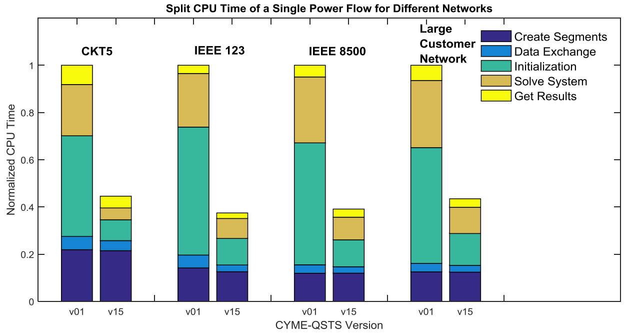


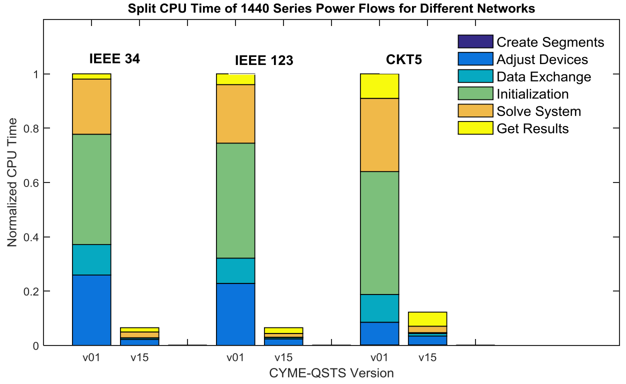
Innovation in Power Flow Algorithms

<u>Objective</u>: Speed up single power flow solutions through improved algorithms, data handling, and memory management

<u>Solutions:</u>

- Initialization using previous solution
- Focused data recording and offloading
- Improve memory management
- Investigate different power flow algorithms
- Decrease controller convergence time





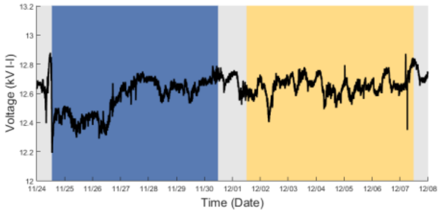
Leveraging More Computational Power

Objective: Solving QSTS is inherently sequential (single-core), but the speed can be improved with more computational power

Solutions:
- Intelligently divide the solution to allow for parallelization (multi-core)
- Many personal computers have multiple cores
- Small clusters or servers can be used for processing (CYME Server)

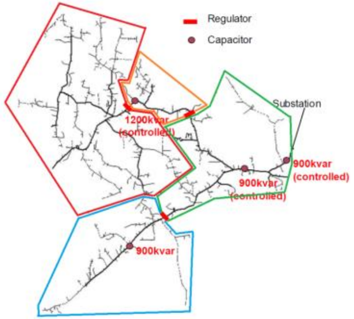
Temporal Decomposition

- Yearlong QSTS is split into individual solutions and computed via multiple cores
- Solutions are "stitched" together after processing, error reducing methods developed



Diakoptics

- Circuit is intelligently divided and power flows for divisions calculated (multi-core)

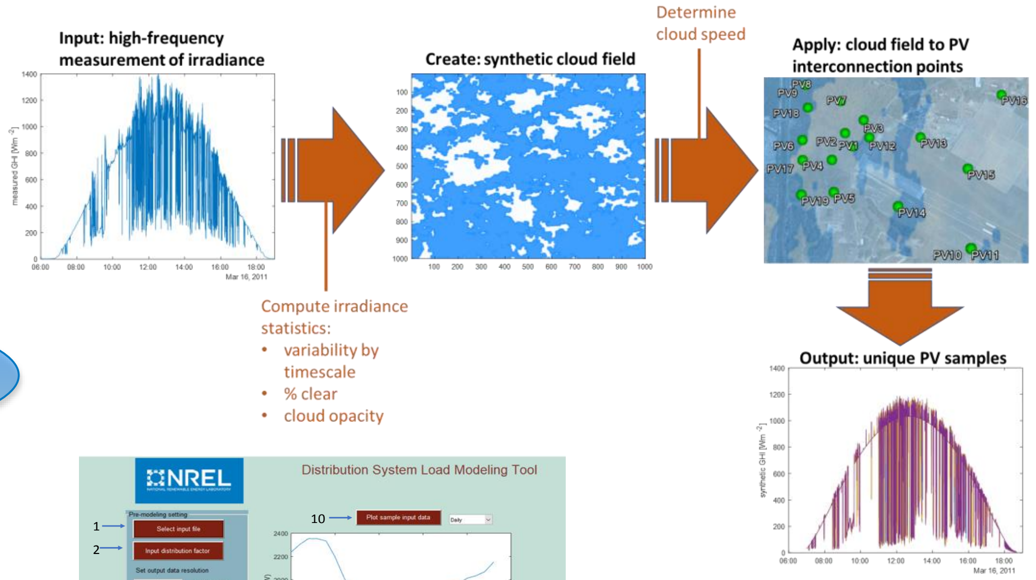


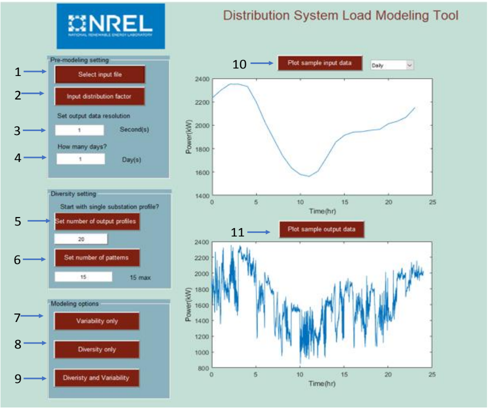
Innovations in Load and Solar Modeling

Objective: Develop data creation methods (proxies) for QSTS inputs not readily available

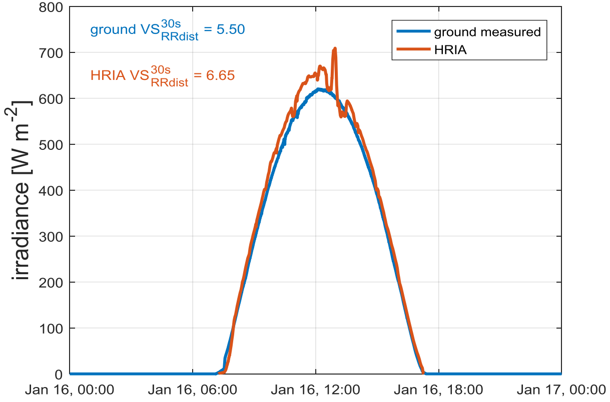
Solutions:

- National high temporal resolution variability data at distribution scale
- Spatial relation of PV output profiles on a feeder/area
- Representative load variability and diversity models





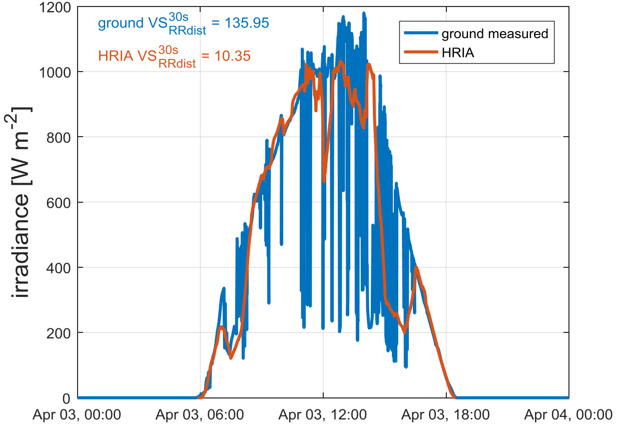
Challenges of National Distribution-Relevant Solar Data

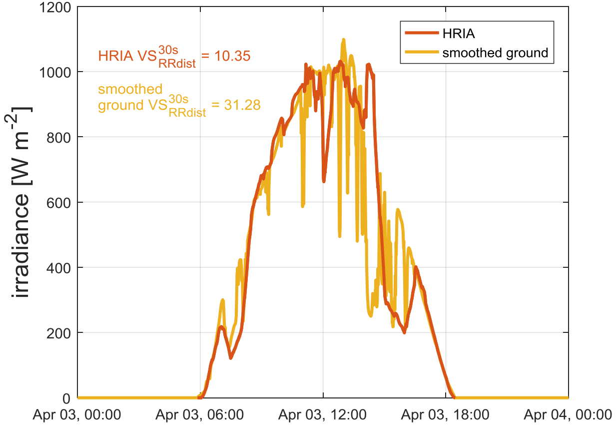


Approach: Start with NSRDB data at 30 minute intervals and model our way to 4 second intervals using real-world ramp rate data (variability data) based on weather regime.

Goal:

- Variability Scores within 10 points of measured (single point) data – highly localized





Other Challenges for Rapid QSTS

Challenges with accepted innovation within the industry:

- Acceptance of circuit reduction for faster QSTS – we sure worked hard putting that model together, then you just reduce it!
- Acceptance of linearized power flow approximations (e.g. event-based simulation) – engineer who use the tools have to understand what is under the hood and classical power flow techniques are the most familiar
- Acceptance of approximation in general

Challenges for getting data in and out of rapid QSTS simulations:

- There is a data paradox for rapid QSTS where the more data included (i.e. the more detailed and accurate the model is) the more it slows down the QSTS run making it less likely to be used – need to find a good balance

Thank you for your attention

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