Modeling PV Penetration Effects with Different Operating Modes

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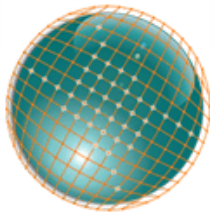

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Conference Sponsors

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Overview

- PV/Storage Communication Project
- Volt/Var Control (VVC)
- Distribution Analysis Tool - OpenDSS
- VVC Implementation Case Studies
  - Steady-State Assessment of Penetration Limits
  - Impact on Voltage Fluctuations
  - Coordination with Conservation Voltage Reduction

PV/Storage Communication Project

Project Overview

- To identify common set of desired functions for smart, communicating inverters
- 350 individuals engaging in the project, representing:
  - 60 utilities
  - 40 PV & Storage equipment providers
  - 12 National labs and research organizations

Phase 1 Functions

- Connect / Disconnect from Grid
- Output Power Management
- **Advanced Volt-Var Control**
- Storage Management
- Event/History Logging
- Status Reporting /Reading
- Time-sync

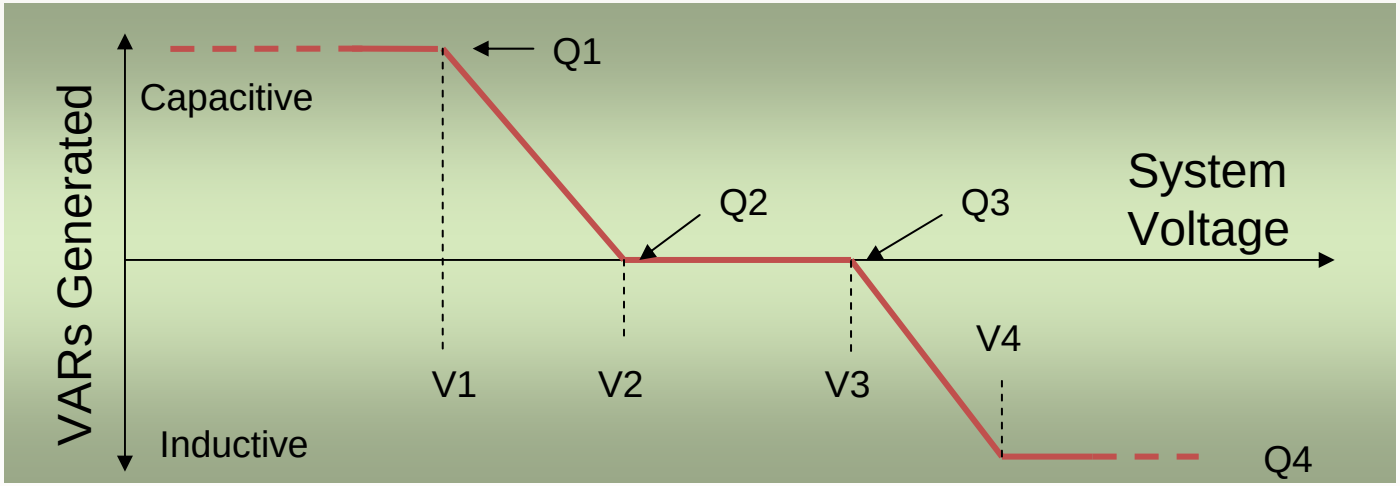
Advanced Volt-Var Control

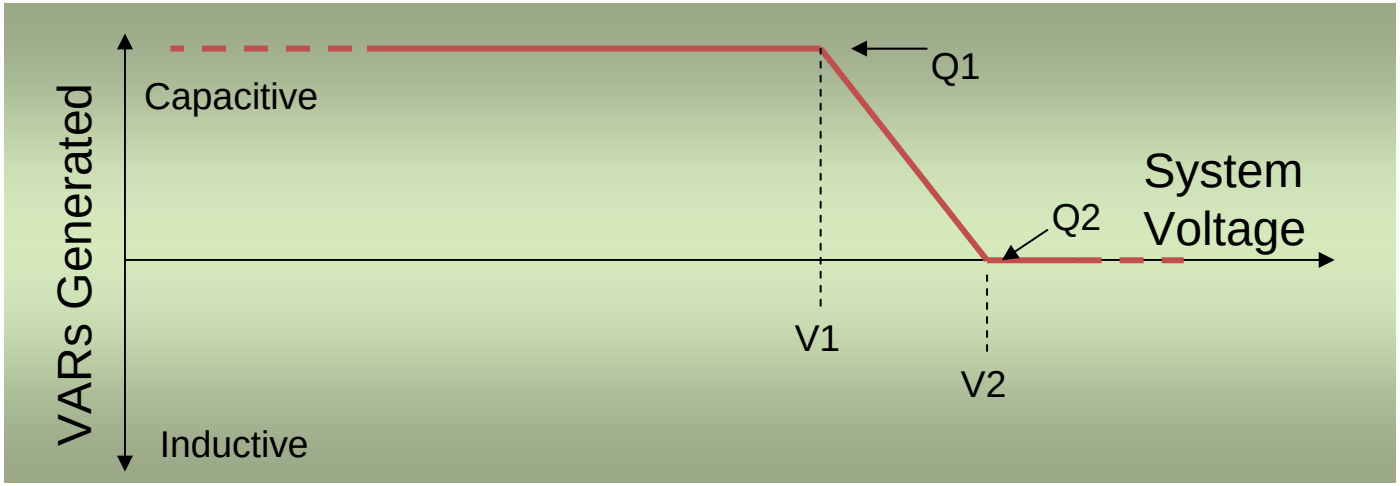
Volt/Var Mode 1 – Normal Regulation

Simple Broadcast

Volt/Var Mode 2 –VAR Support

Utility-Defined Curve Shapes





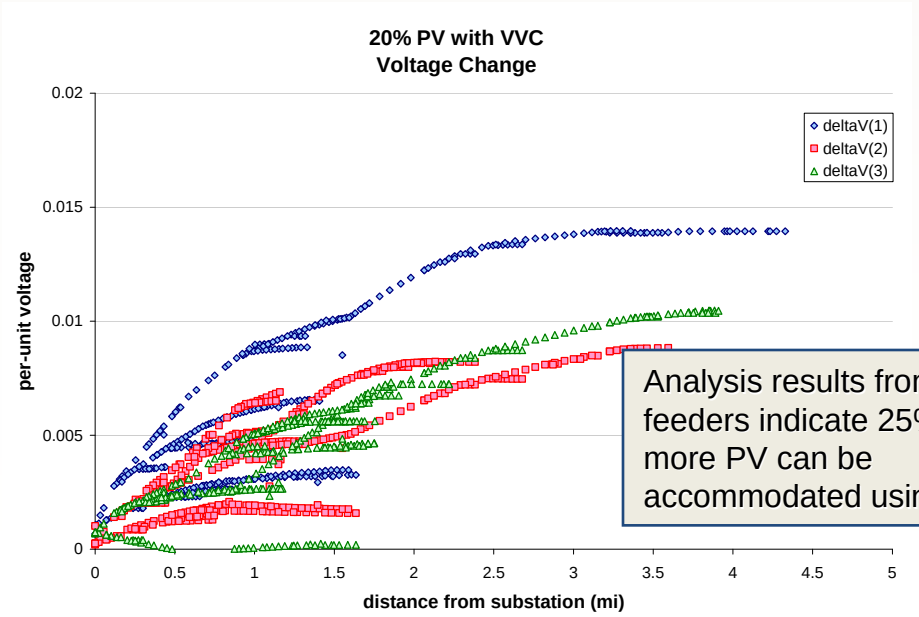
Advanced Simulation Platform -- OpenDSS

- Open source of EPRI's Distribution System Simulator (DSS)
  - developed in 1997
  - open sourced in 2008 to collaborate with other research projects
- OpenDSS designed from the beginning to capture
  - Time-specific benefits **and**
  - Location-specific benefits
- Differentiating features
  - full multiphase model
  - numerous solution modes
  - "dynamic" power flow
  - system controls
  - flexible load models
- Needed for analysis of
  - DG/renewables
  - energy efficiency
  - PHEV/EV
  - non-typical loadshapes

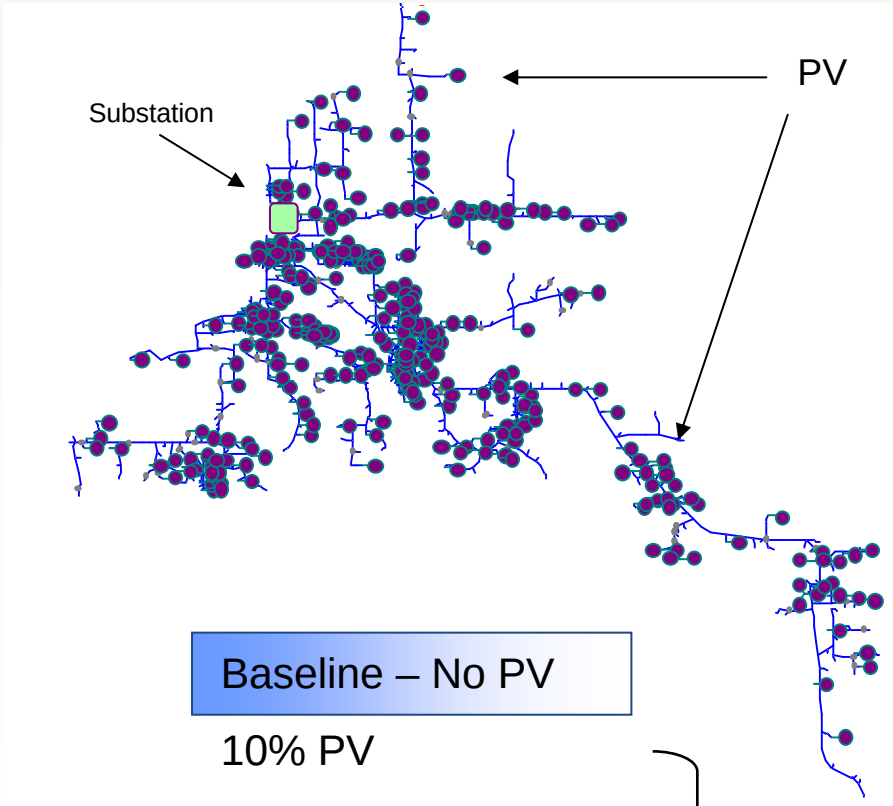
Download for free from
http://sourceforge.net/projects/electricdss

Steady-State Voltage

- Maximum change in voltage
- PV at increased penetration until limit exceeded
- Use of volt/var control accommodates added PV before violations occur



Analysis results from other feeders indicate 25%-100% more PV can be accommodated using VVC



Baseline – No PV

10% PV

15% PV

20% PV

20% PV and VVC

ΔV

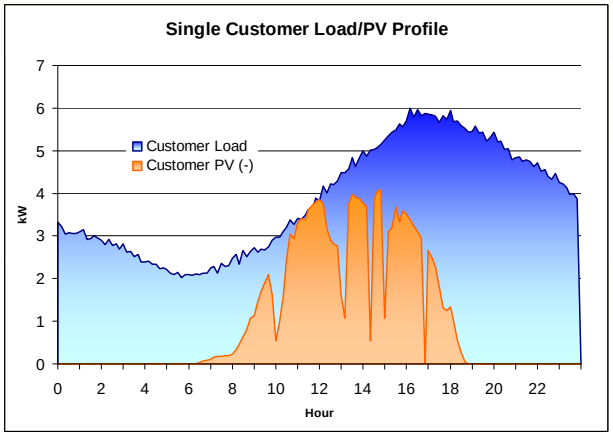
Impact on Voltage Fluctuations

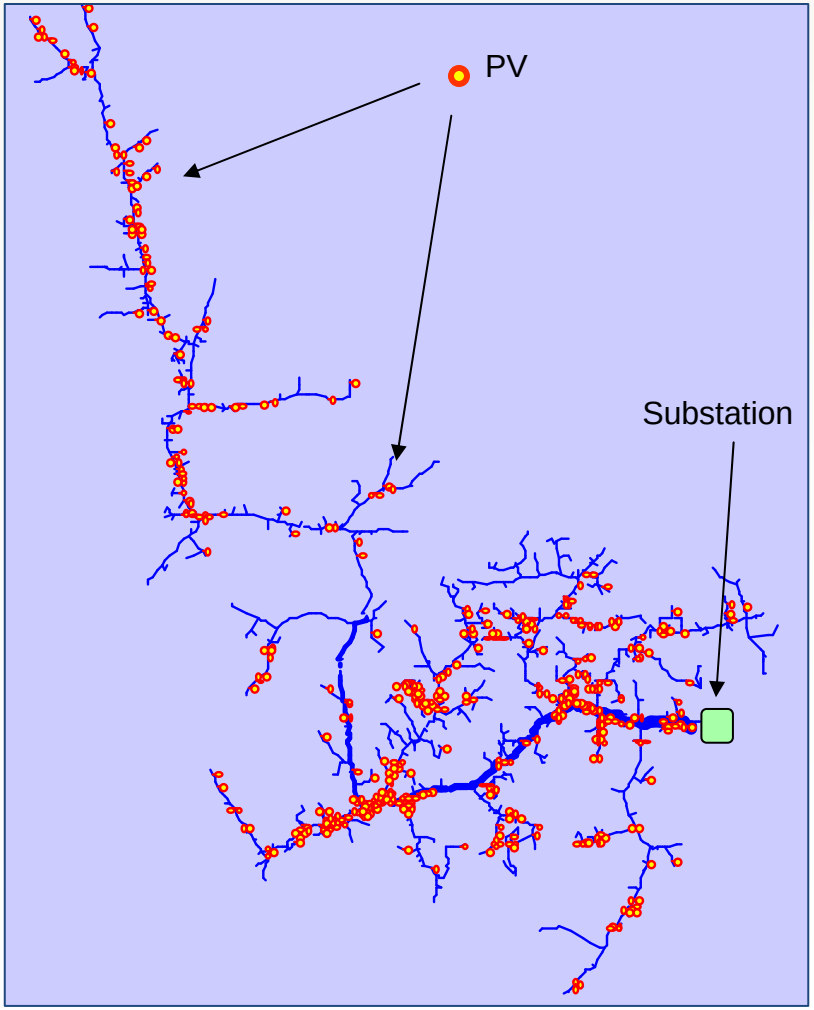
Feeder Details

- 12kV feeder
- 1800 Customer loads
- 10 MW peak load
- 17 mi 3-phase primary
- 115 mi 1-phase primary

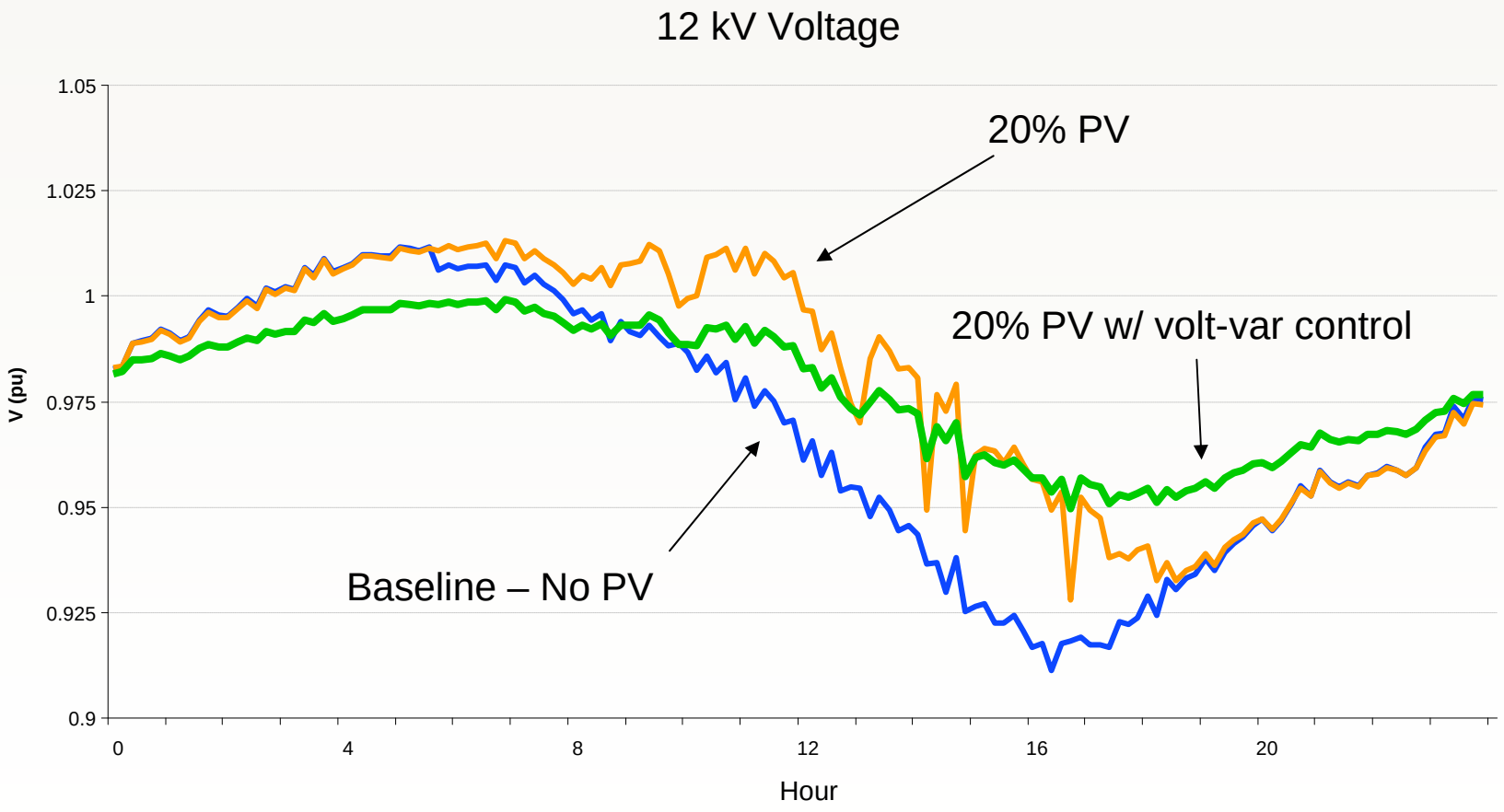
PV

- 20% PV Penetration (% of peak demand) = 450 customers w/ PV
- Randomly selected throughout the feeder

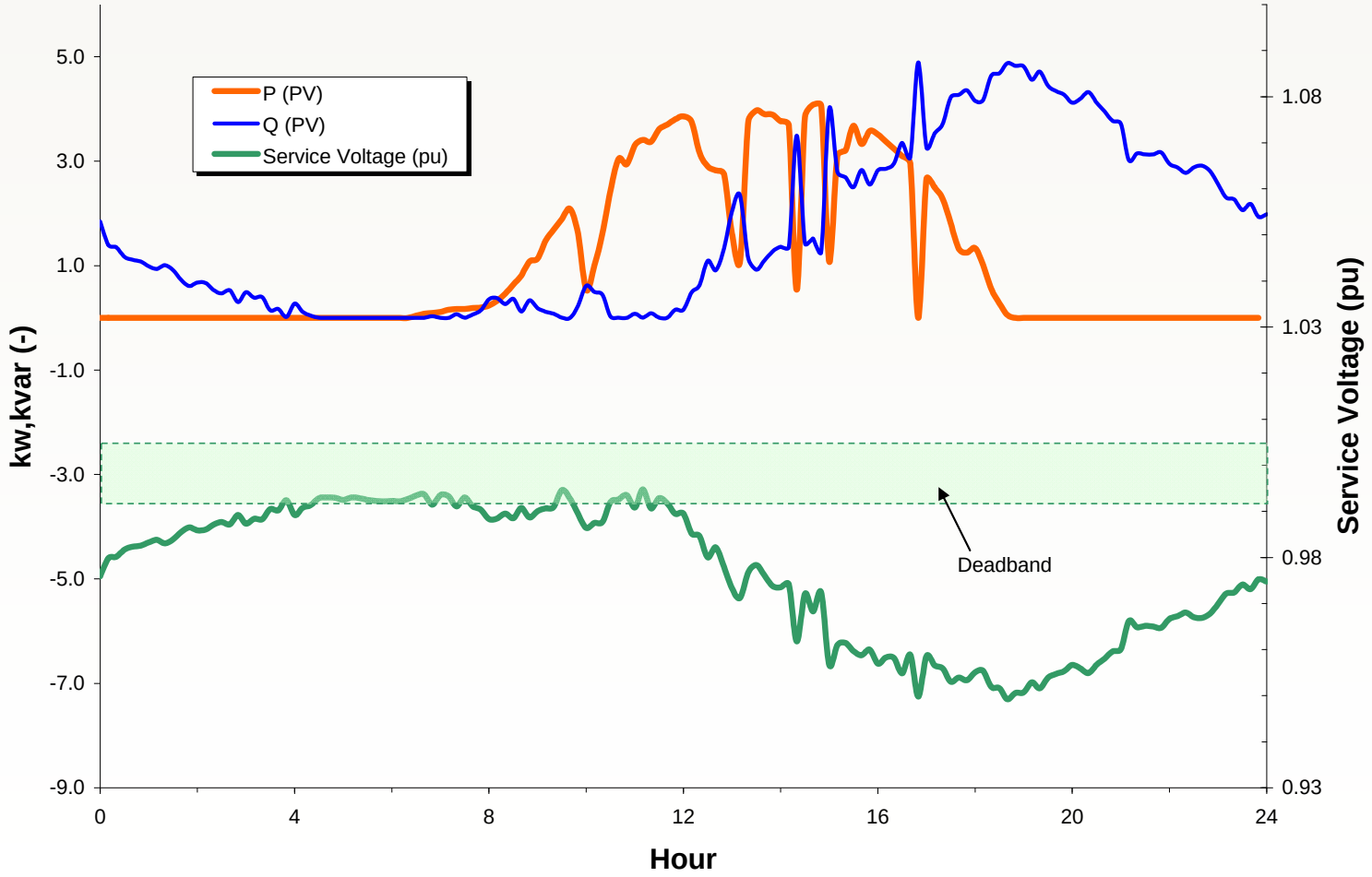




Primary Voltage Response with Volt/Var Control

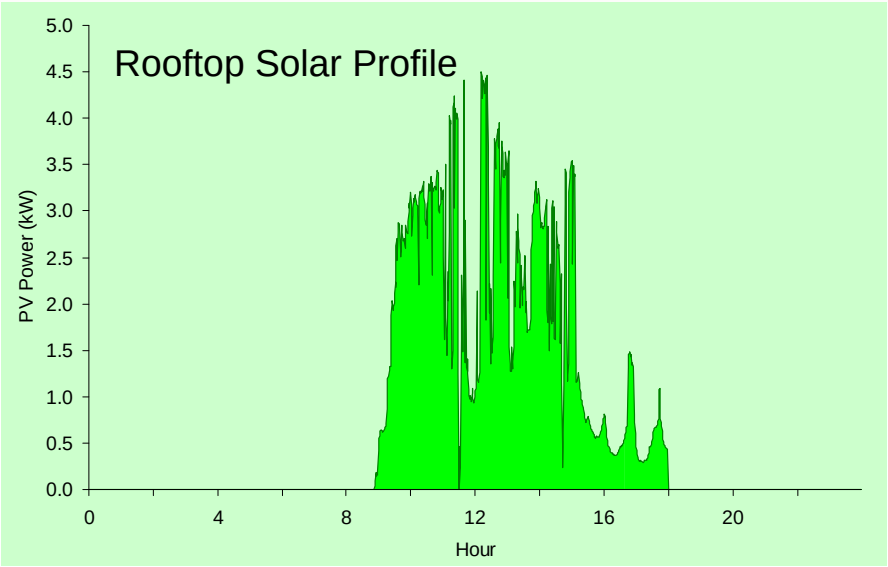


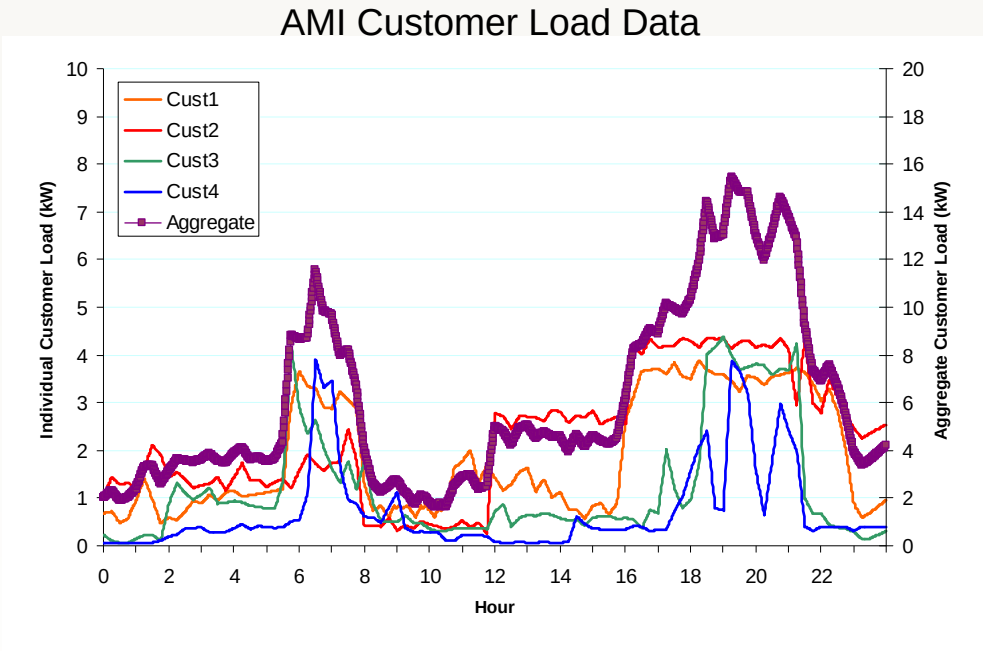
Single Customer Service Voltage with Volt/Var Control



Volt/Var Control with CVR

- Typical loads served from single service transformer
- Considering both time-varying customer
  - Load
  - PV
- 24 hour period

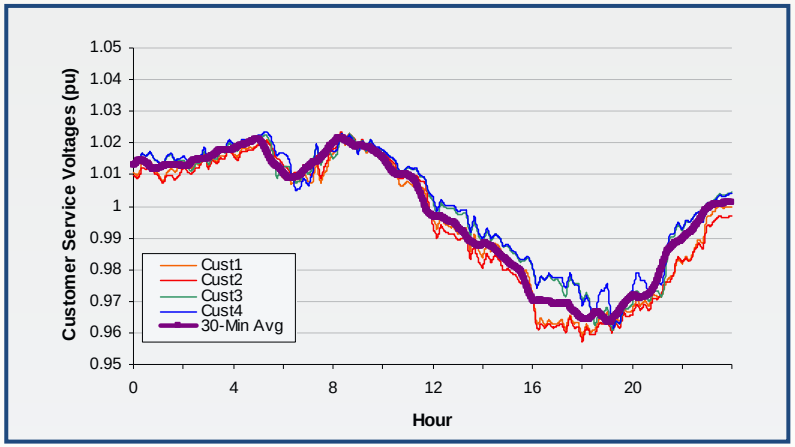




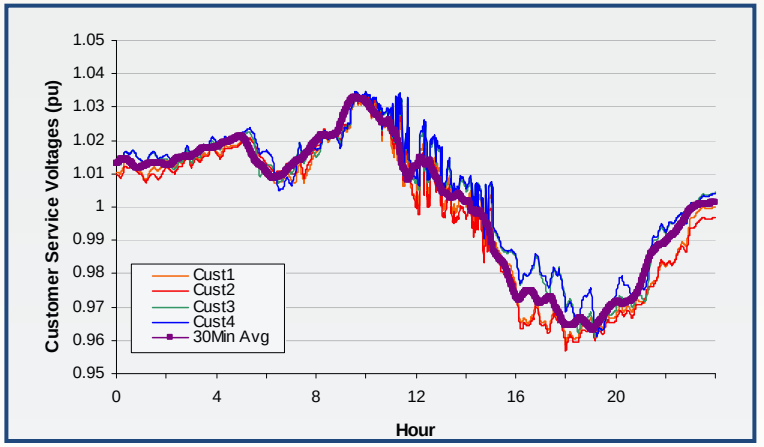
- Volt/var control
  - reduced setpoint to 117V (0.975 pu)
  - No deadband

Volt/Var Control for CVR – Sample Results

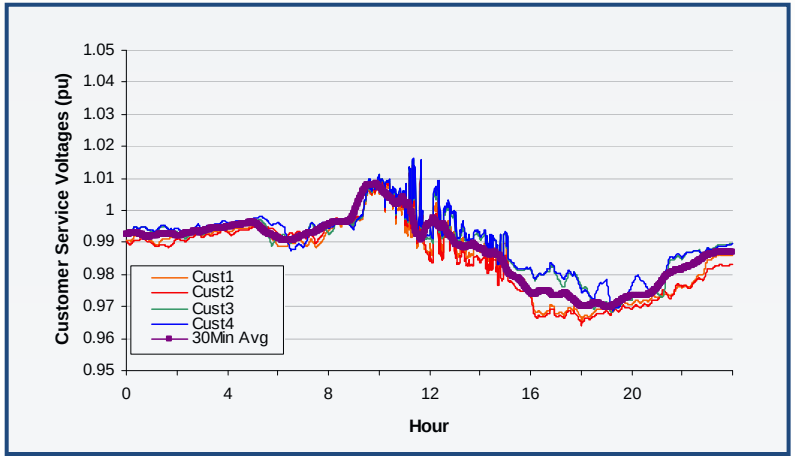
Baseline - No PV



With PV



PV with Volt/Var Control



- Energy Consumption
  - + 0.2% with PV
  - - 0.4% with PV and volt/var control
- Analysis has shown increased penetration at the feeder level has even greater impact
- Other volt/var curves can be “dispatched” to coordinate with utility CVR programs
- Simulations allow testing under a wide range of conditions

Conclusion

- PV with autonomous volt/var control
  - Can help mitigate voltage fluctuations caused by PV
  - Can “flatten” feeder voltage profiles
  - Coordinate with CVR
  - Limited communication required
- Further work
  - Adaptive setpoint
  - Inverter losses
  - Thresholds of operation

Question & Answer