Distribution System Analysis for Smart Grid

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Webcast

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EPRI Power Systems Modeling/Analysis Group

- Resource group -- systems modeling, simulation, analysis
- Consulting services from generation to end-use
- Resource support for R&D collaborative efforts

  - Transmission planning
  - Operations
  - Distribution planning and operations
  - Substation design
  - Power quality

The Smart Grid

- SG is different things to different people
  - Communications and control
    - Typically not represented in DSA (at present)
  - Distributed Resources
    - Generation, Storage, Demand Response
      - Test Feeders WG has done large induction machines
  - Monitoring
  - Protection
  - Energy Efficiency

Smart Grid Features

- Distributed Resources
  - Generation
  - Renewable Generation
    - Variable sources
  - Energy Storage
  - Demand Response

Smart Grid Features, cont'd

- Communications and Control
  - AMI deployed throughout the system
  - High-speed communications to Metering and Controls
  - State Estimation

Impact of SG on Distribution System Analysis?

- What DSA framework is needed to support all features of the SG?
- Will there be a need for DSA if everything is monitored thoroughly?
- What could we do if we know more about the system?
- How will merging of planning, monitoring and DSE change DSA tools?

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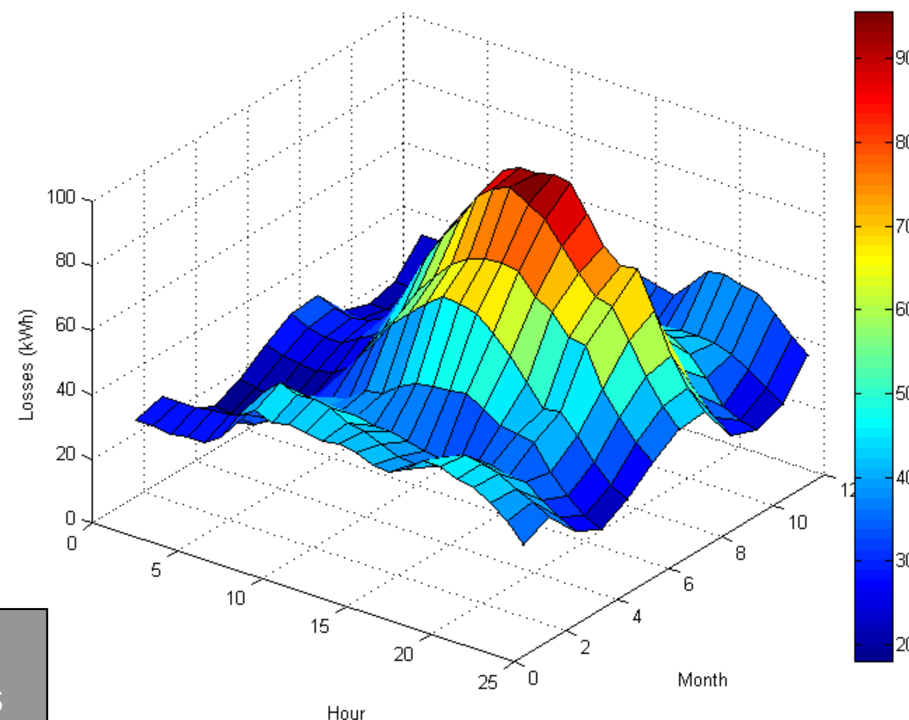
Role of Distribution System Analysis

- Distribution state estimation
- Emergency reconfiguration
  - Account for missing data, failed comm
- EPRI vision
  - Planning and DMS will converge into one set of tools (Real time and planning will merge)
- Continued need for DSA tools
  - Different form and more capabilities

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 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

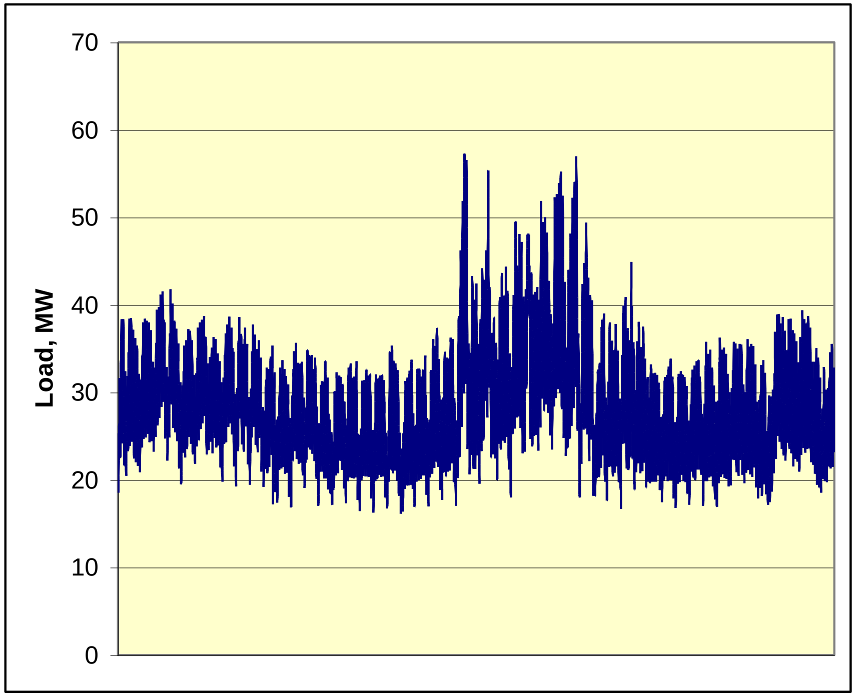
- Needed for analysis of
  – DG/renewables
  – energy efficiency
  – PHEV/EV
  – non-typical loadshapes

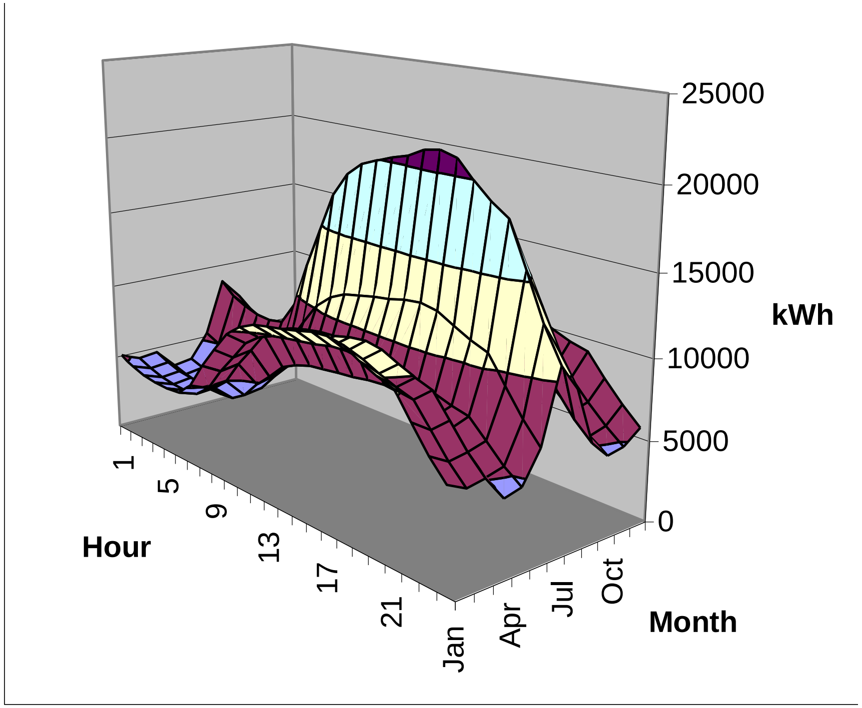


Download for free from
http://sourceforge.net/projects/electricdss

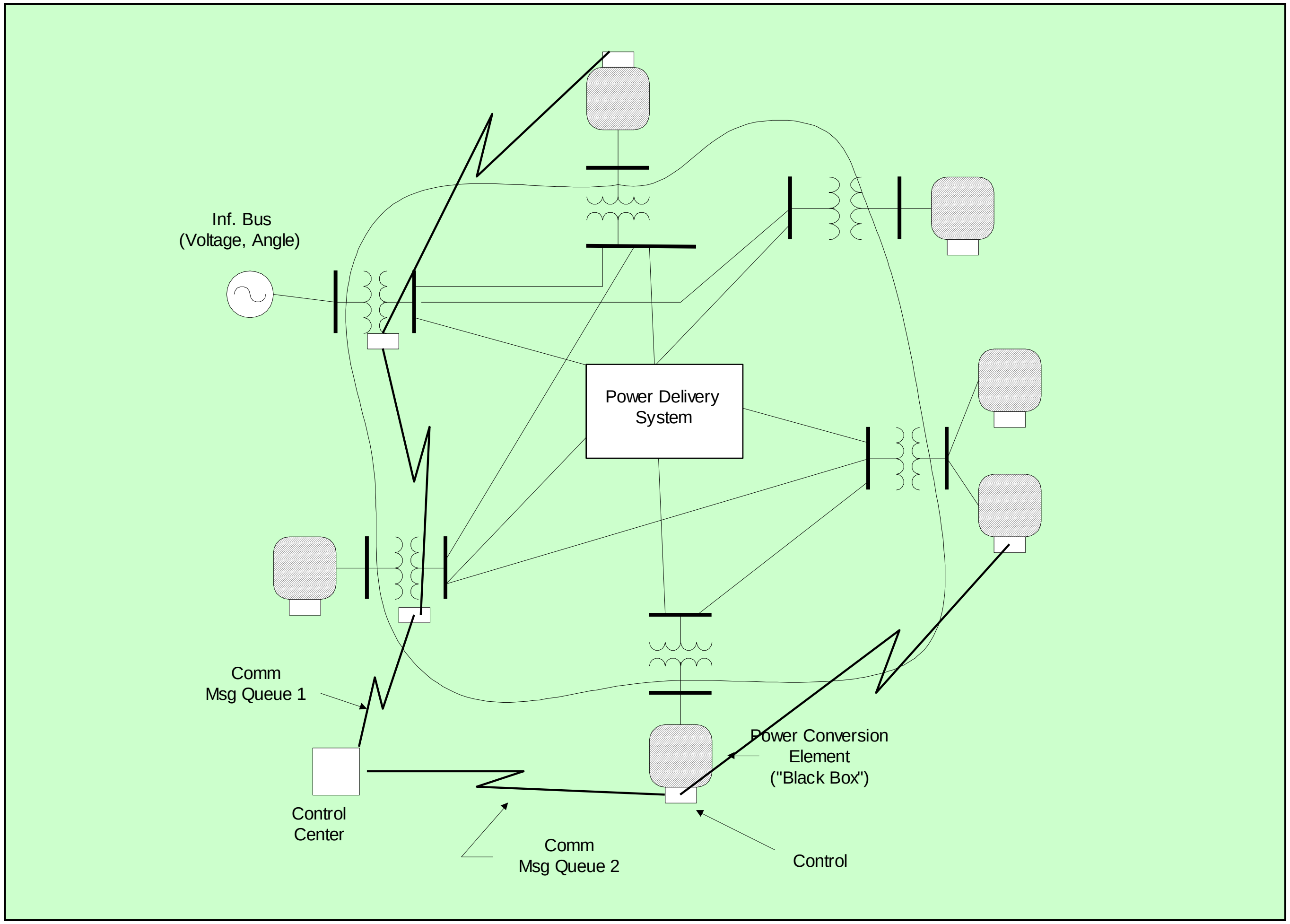
Computing Annual Losses

Peak load losses are not necessarily indicative of annual losses





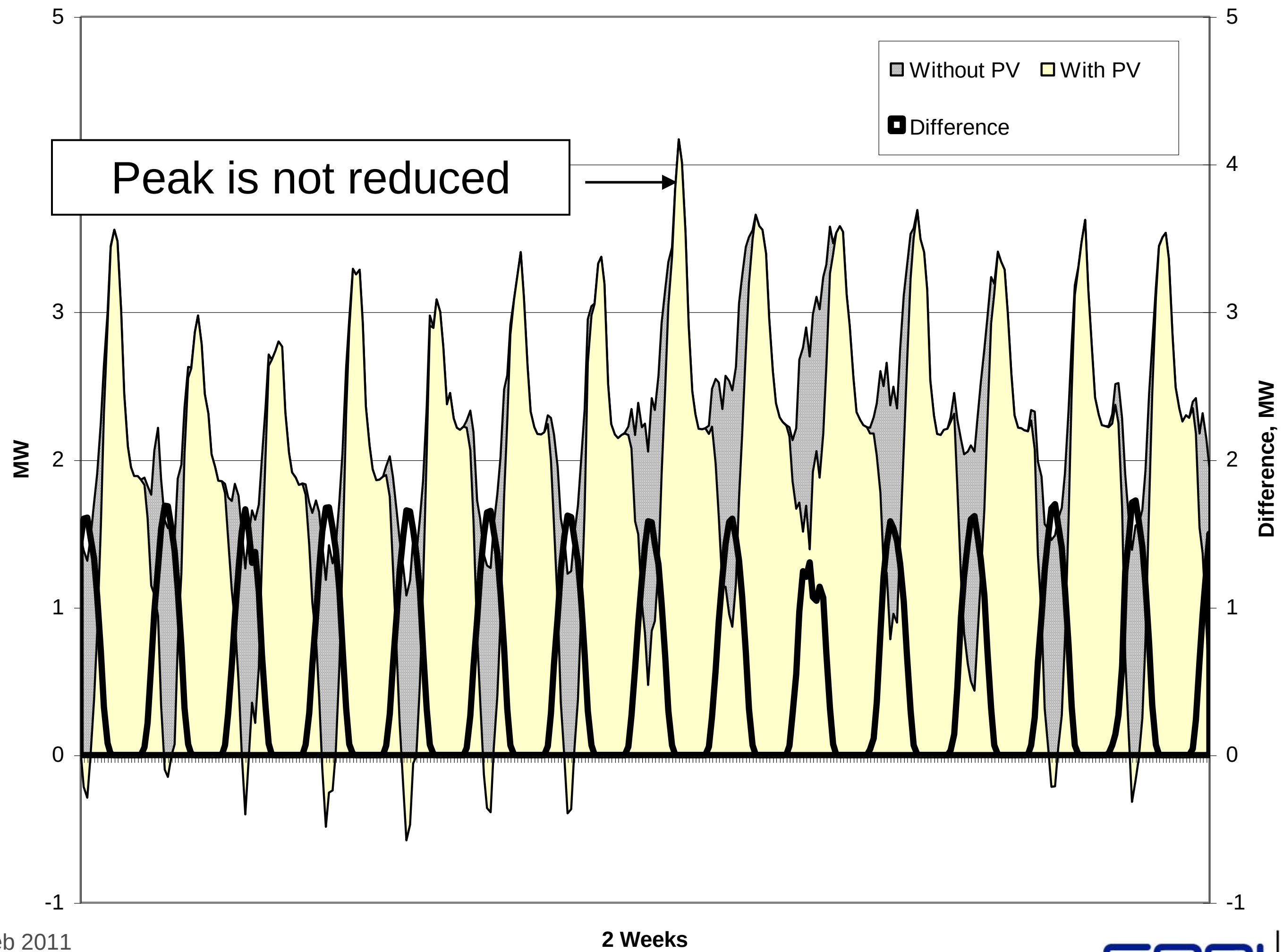
Overall Model Concept



Supporting Renewables

Solar PV Simulation 1-hr Intervals

What is the Capacity Gain?



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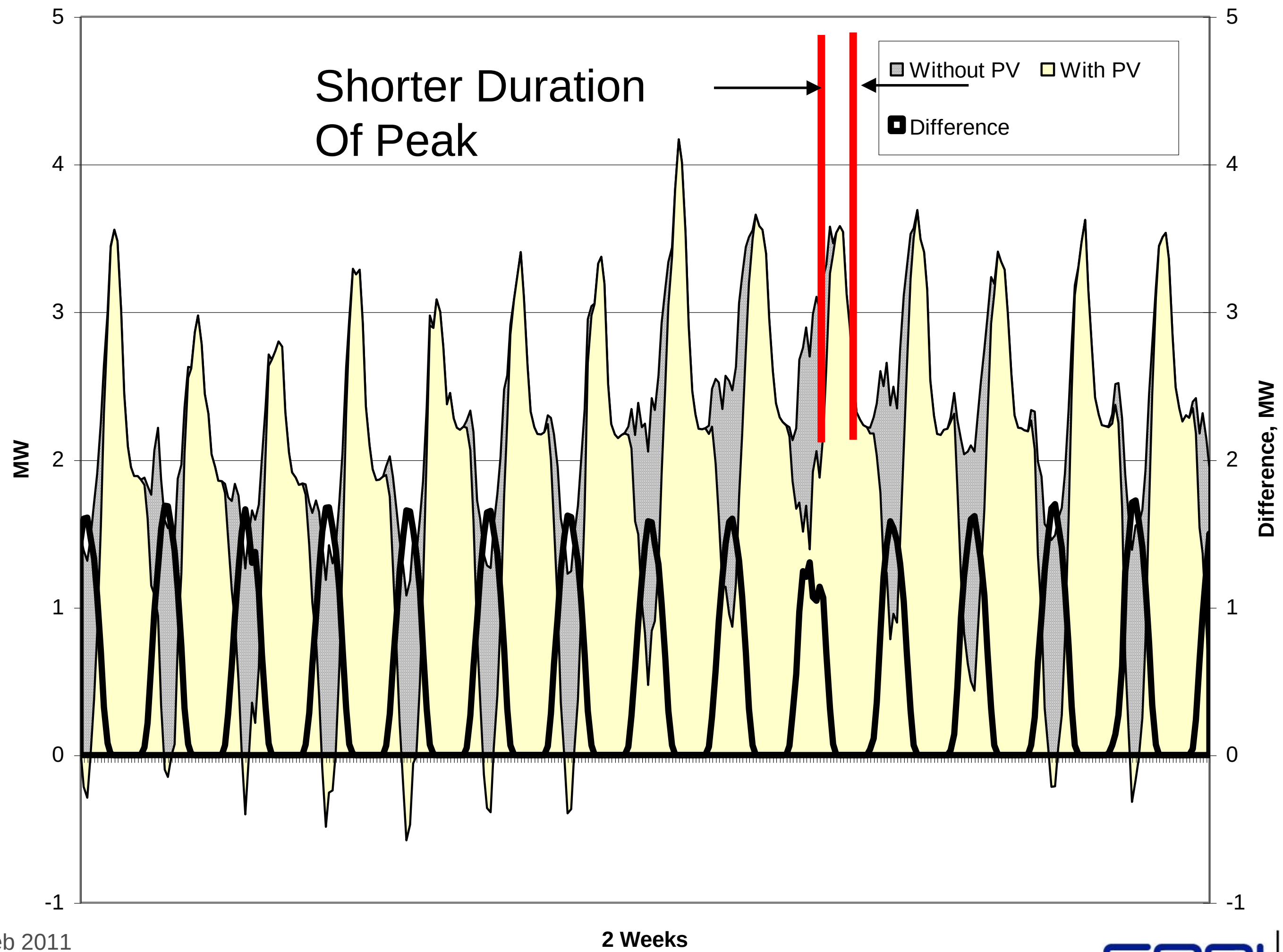
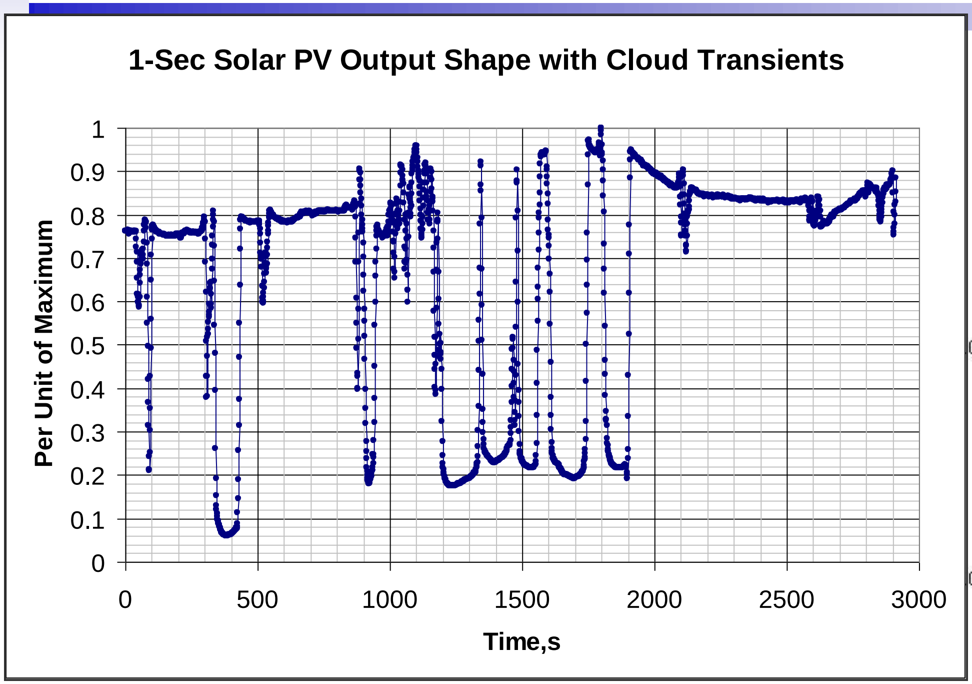
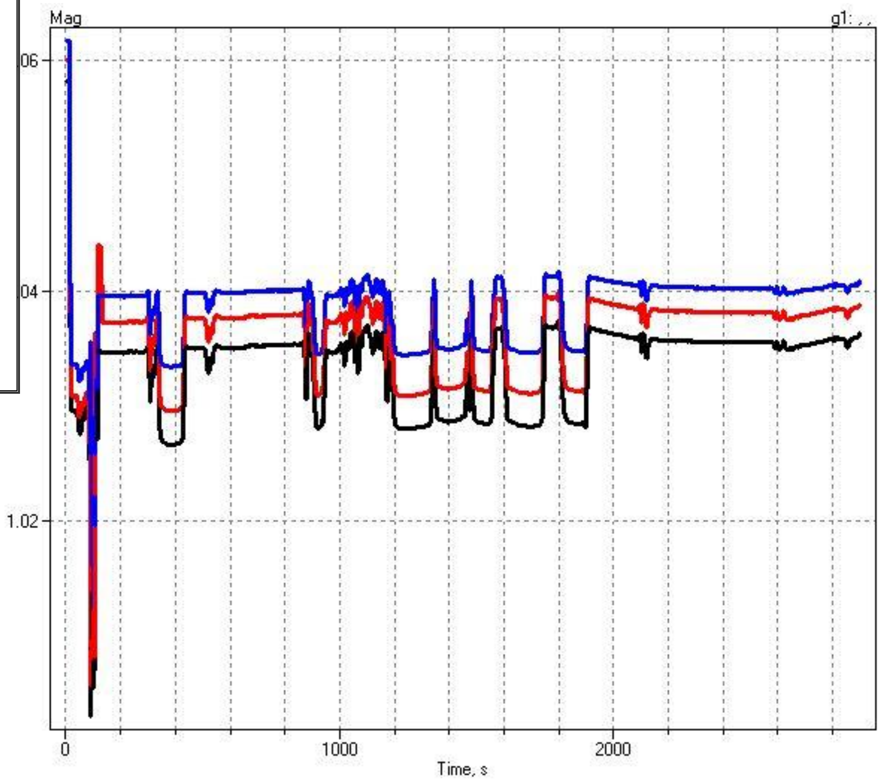
Can DMS Enable Increased Capacity?



Cloud Transients: 1-sec Interval



Impact on Feeder Voltage



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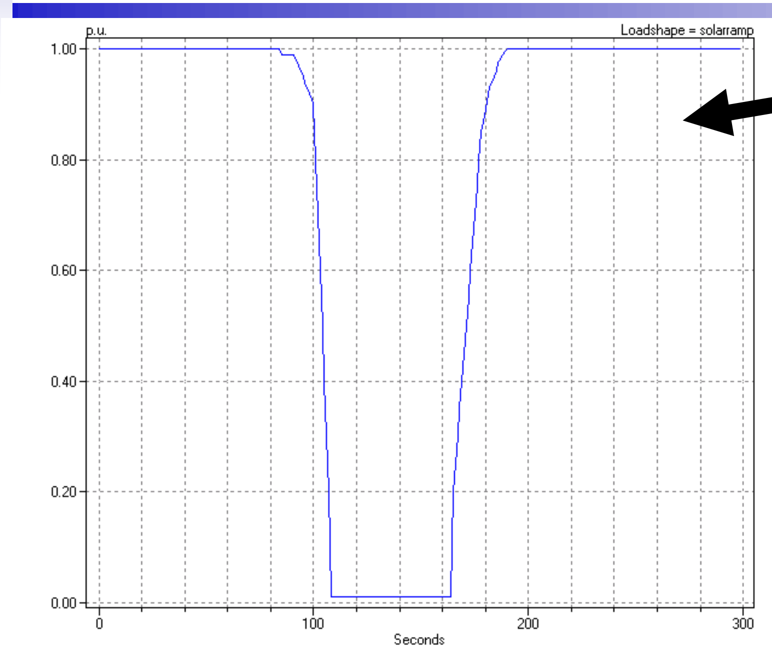
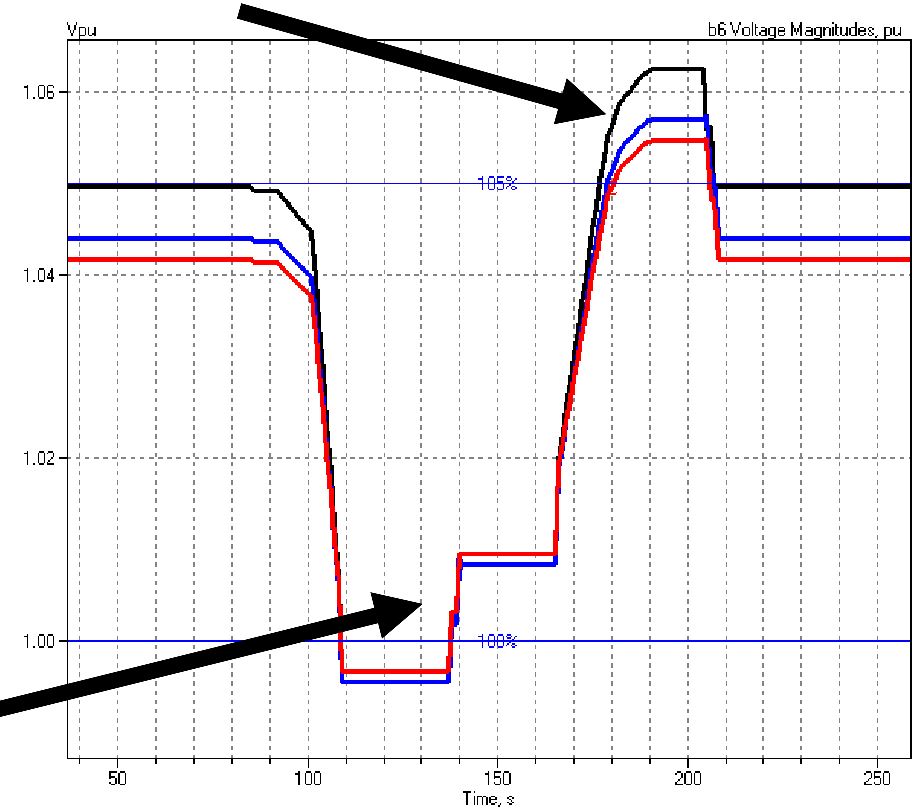
Solar Ramping



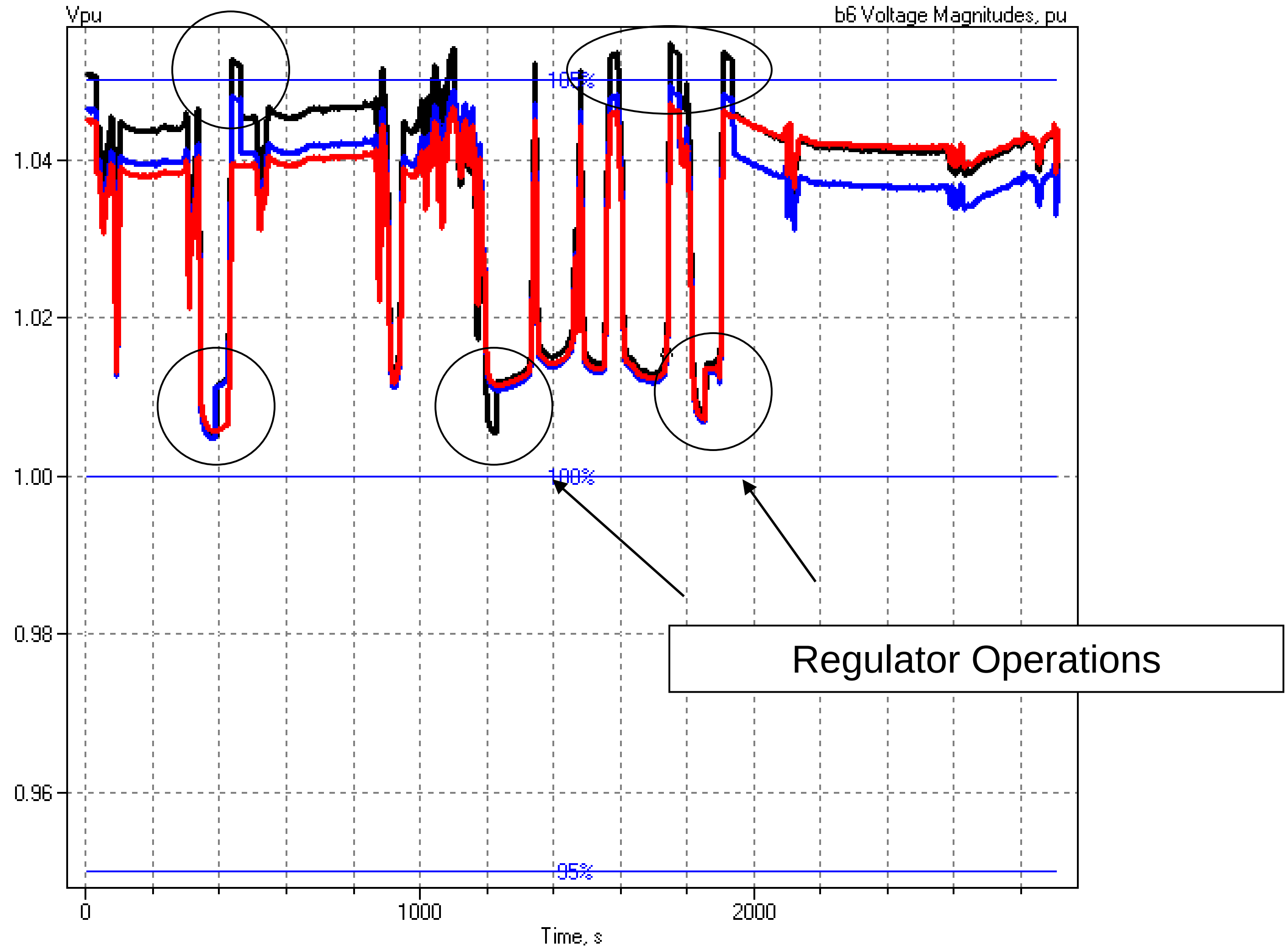
Basic Solar Ramp Function

Voltage Pushed over limit on recovery



Regulators compensate for drop

Regulator Response for Series of Cloud Transients



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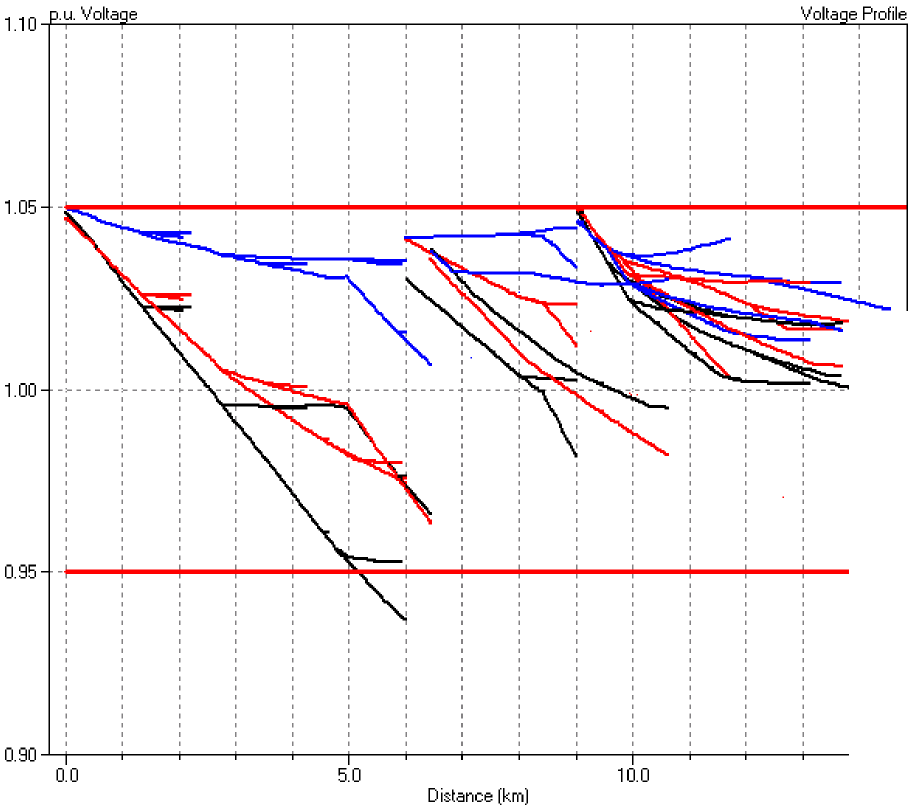
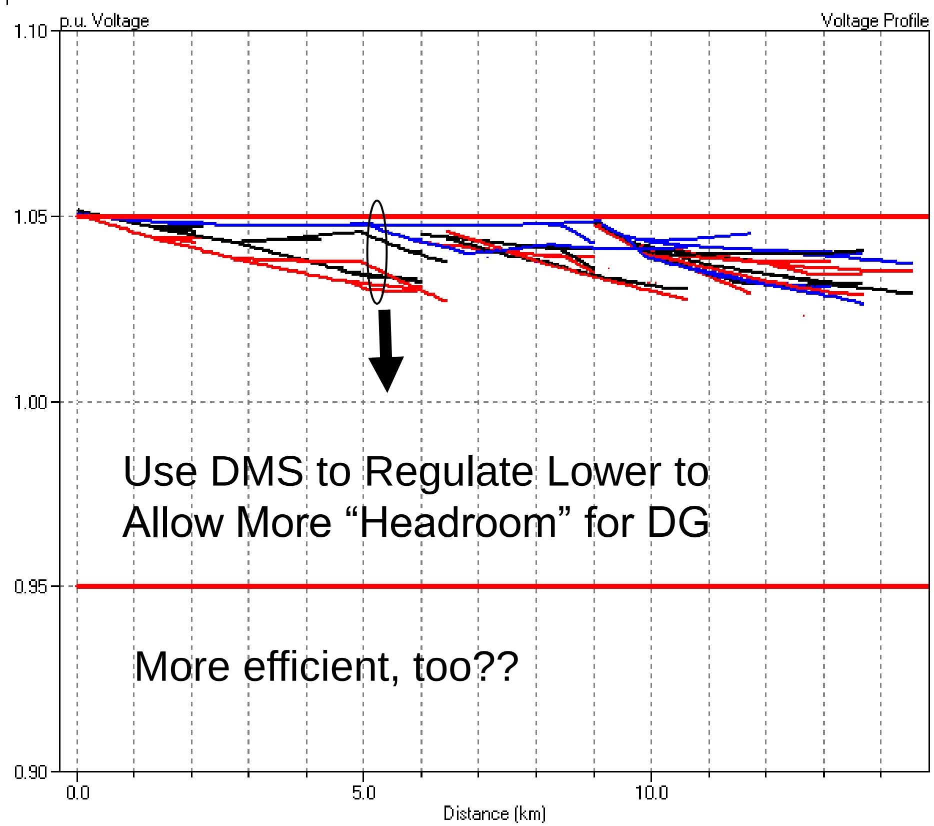
“Headroom” for PV



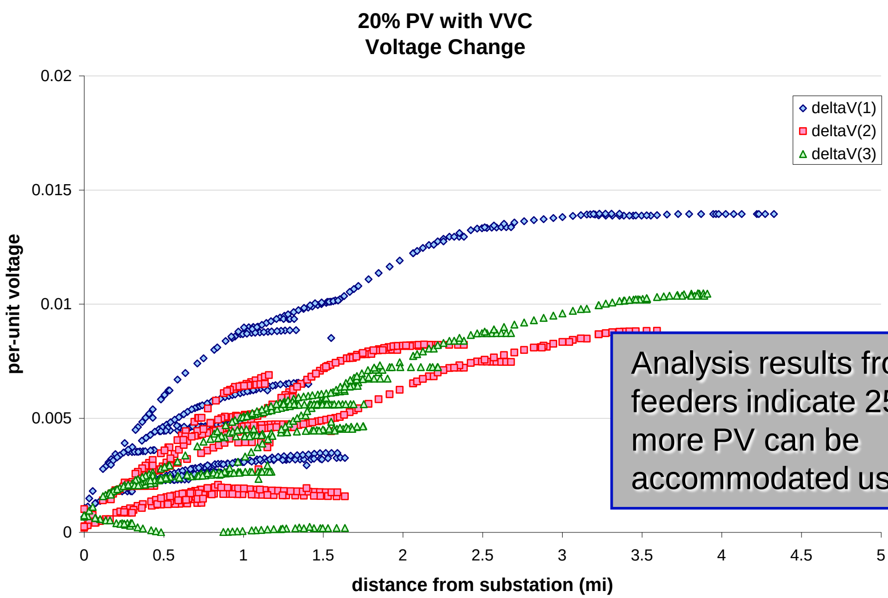
Voltage Profile for 100% Load

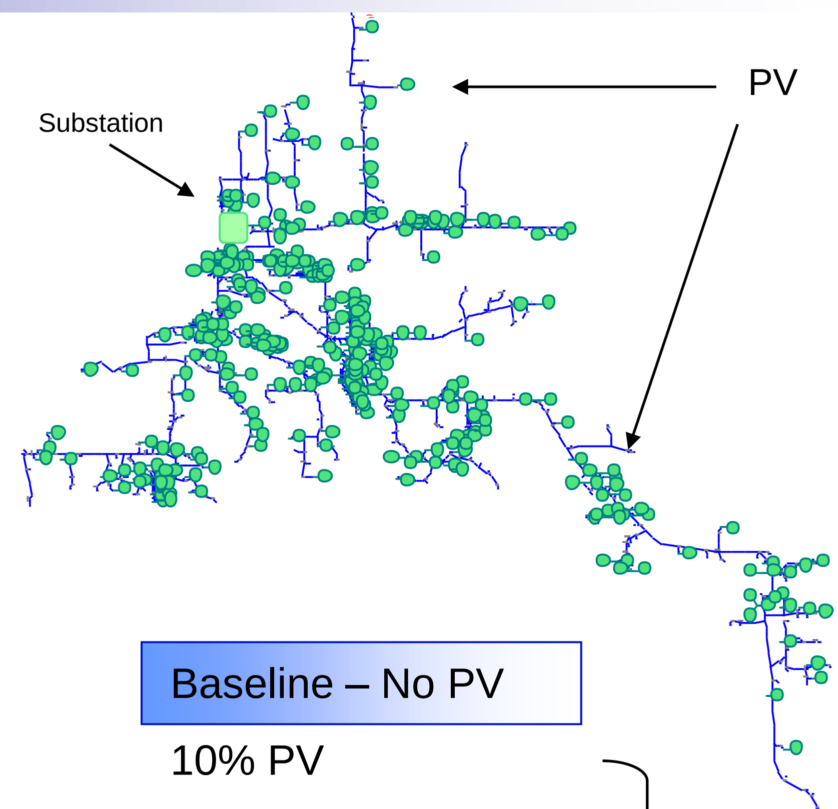
Voltage Profile for 40% Load



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

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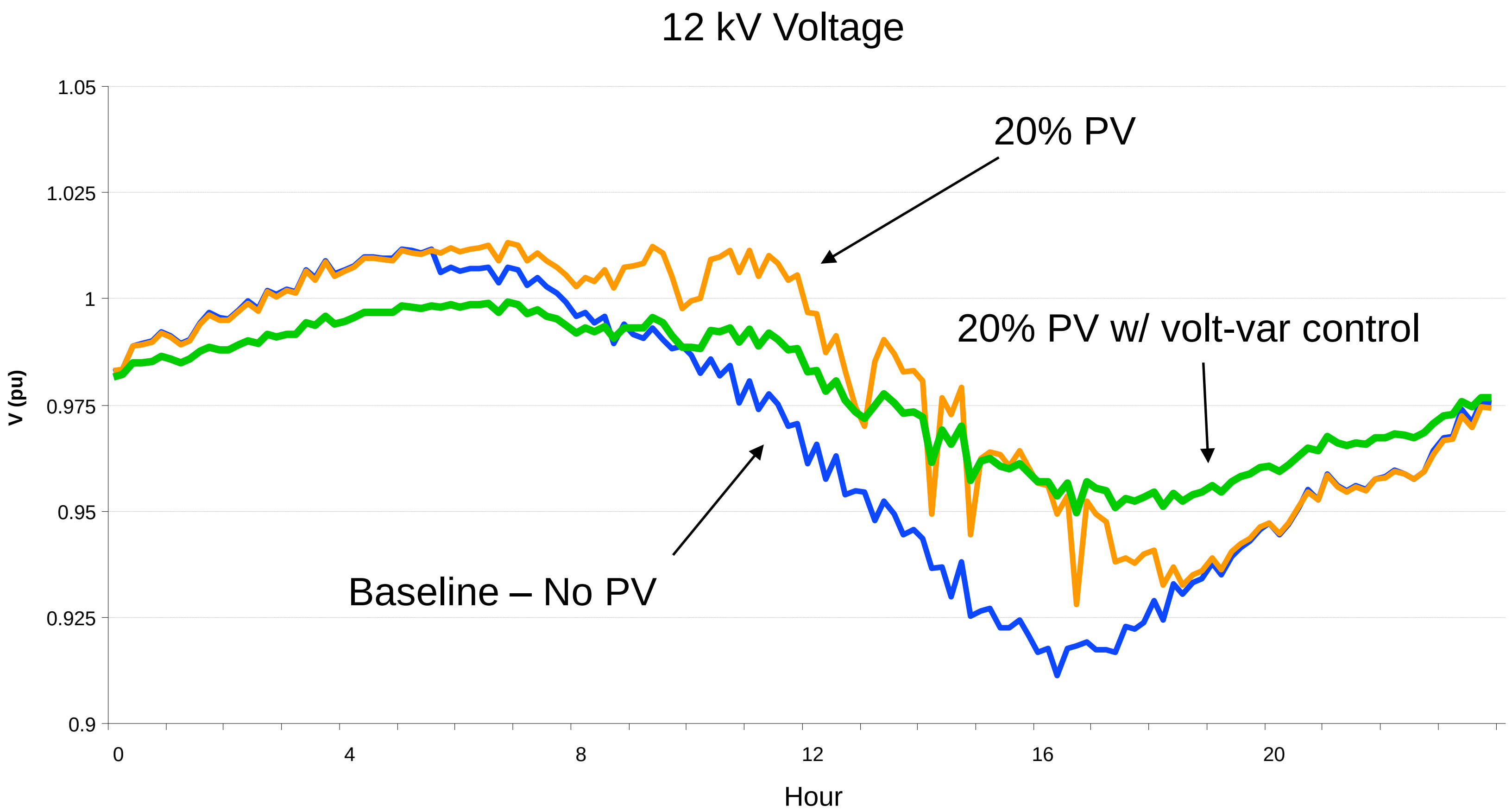
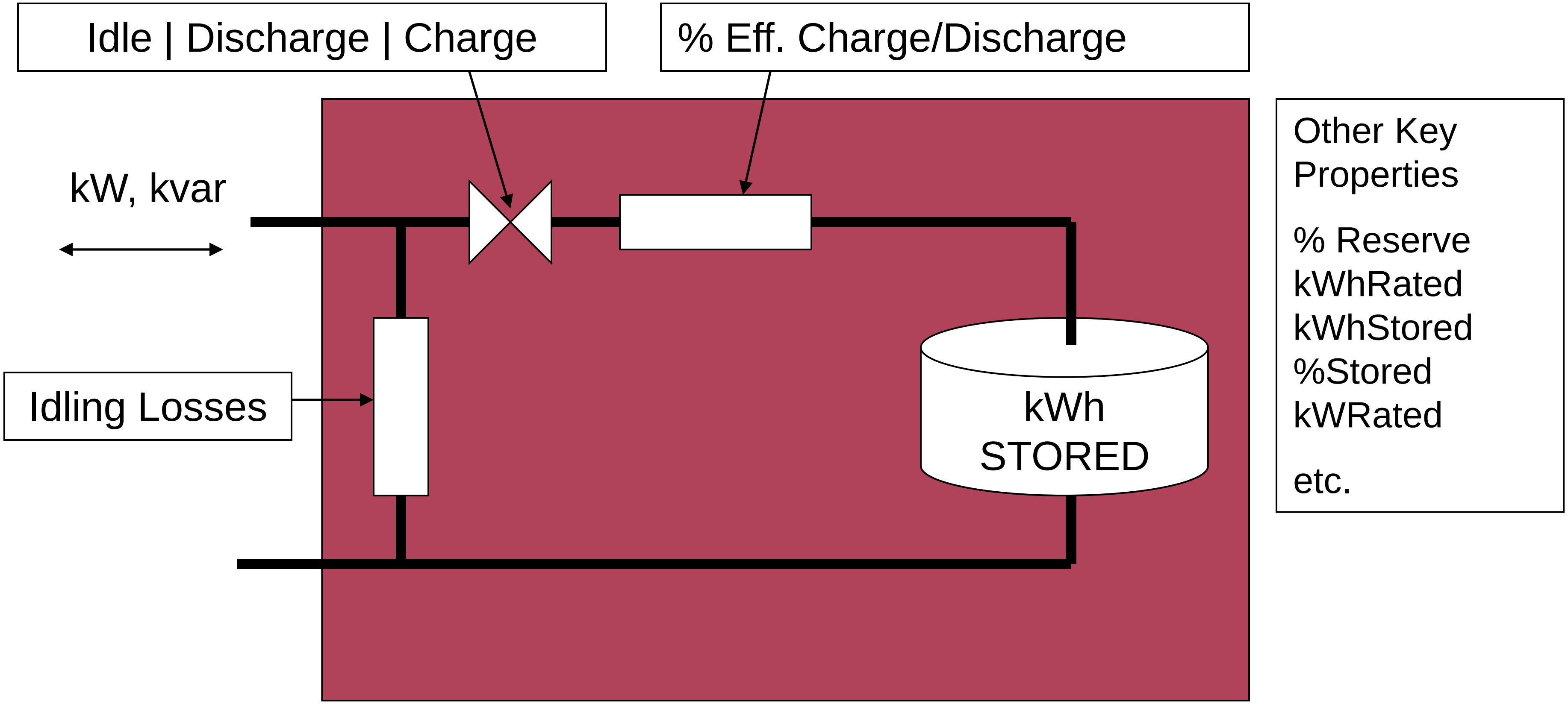
Primary Voltage Response with Volt/Var Control

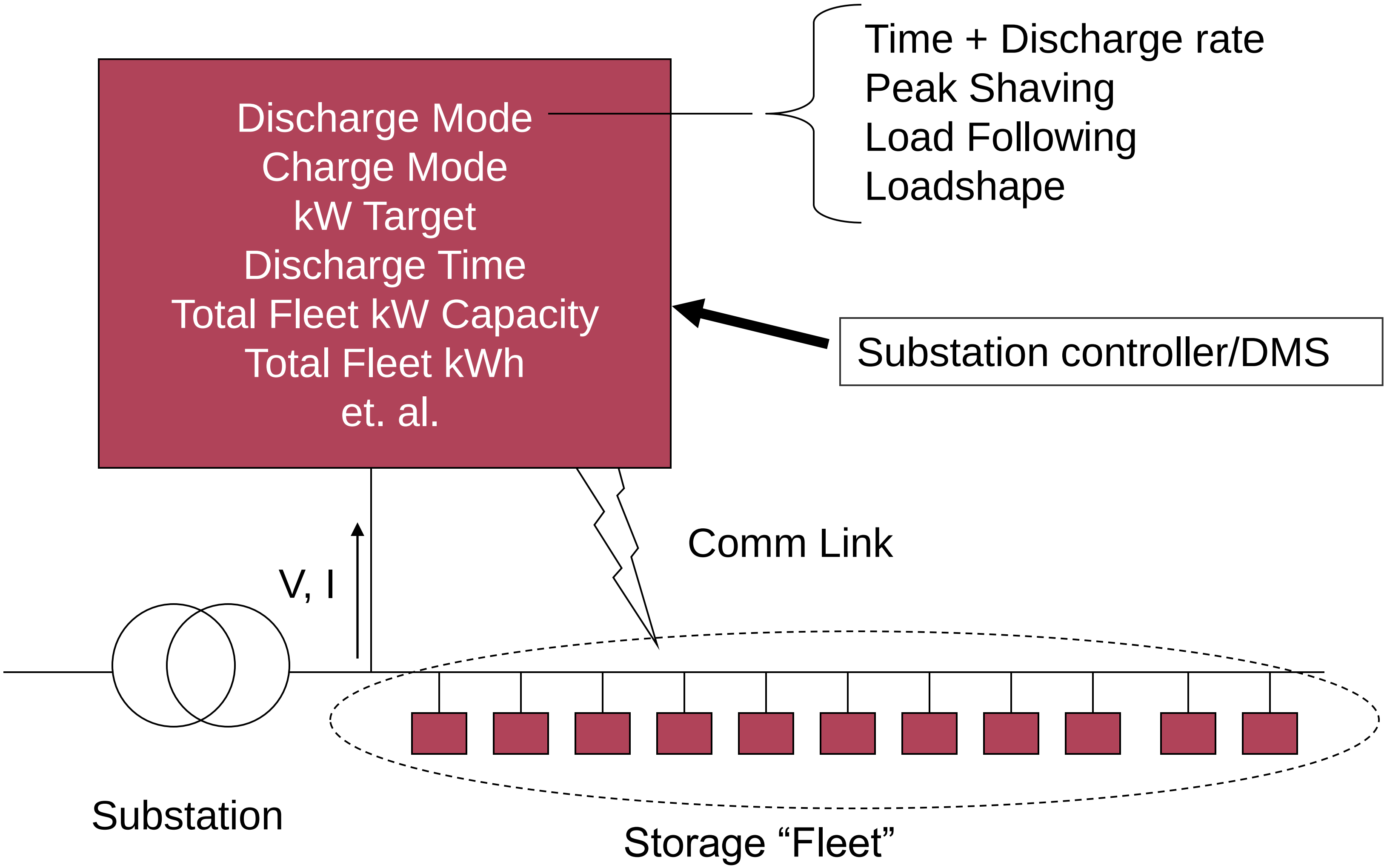


Storage

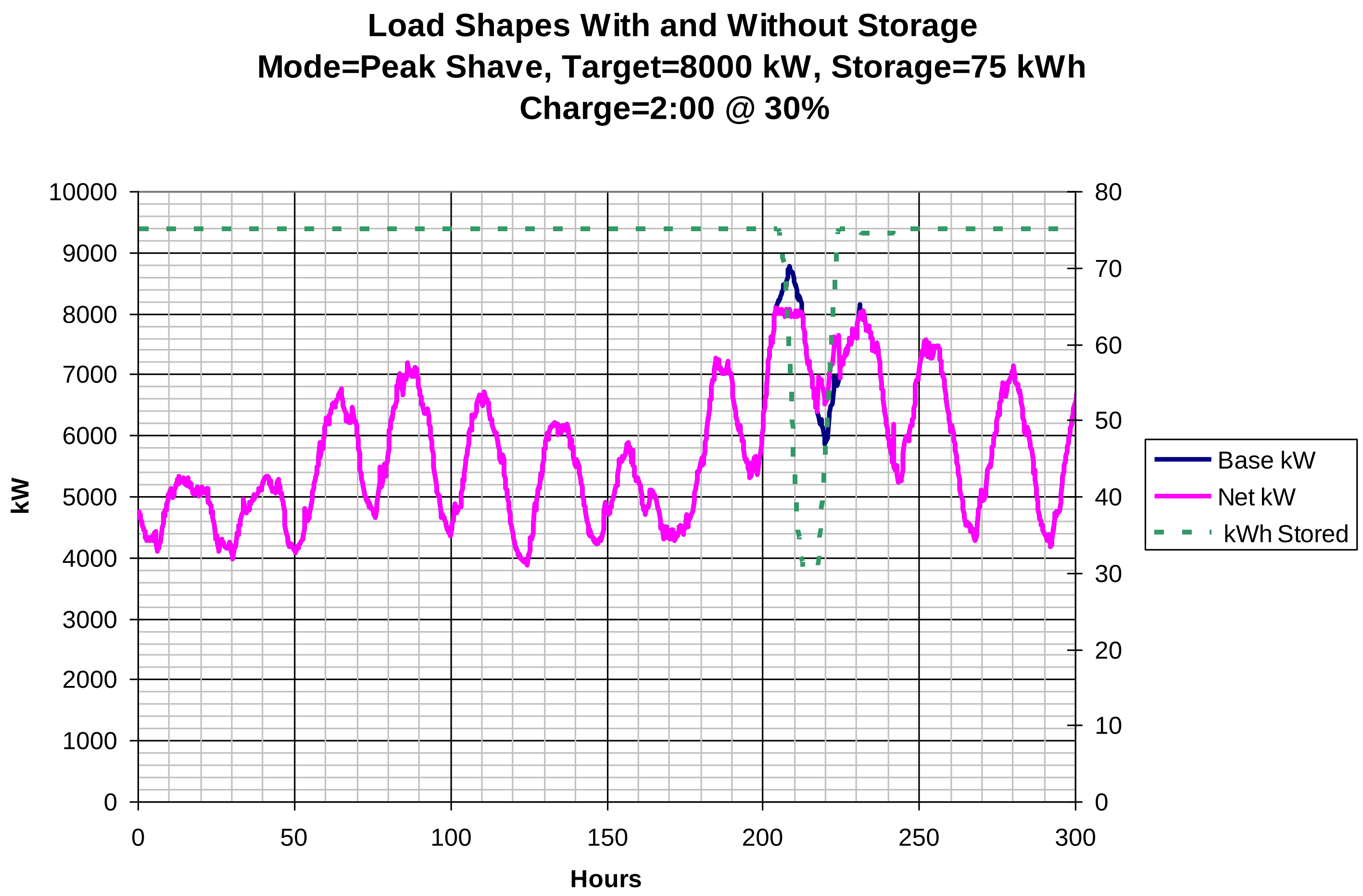
Generic Storage Element Model (OpenDSS Model)



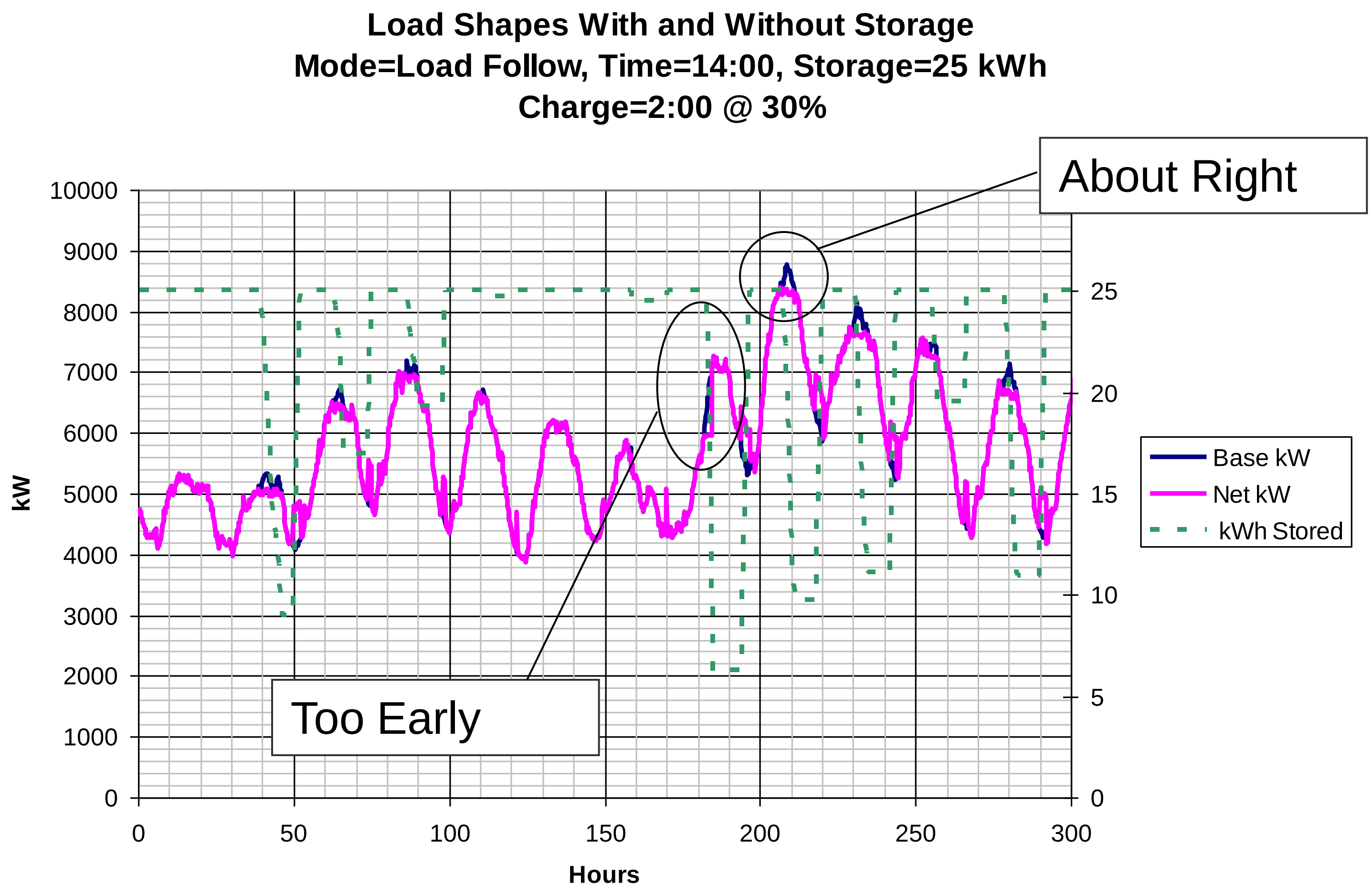
Controlling Storage from DMS



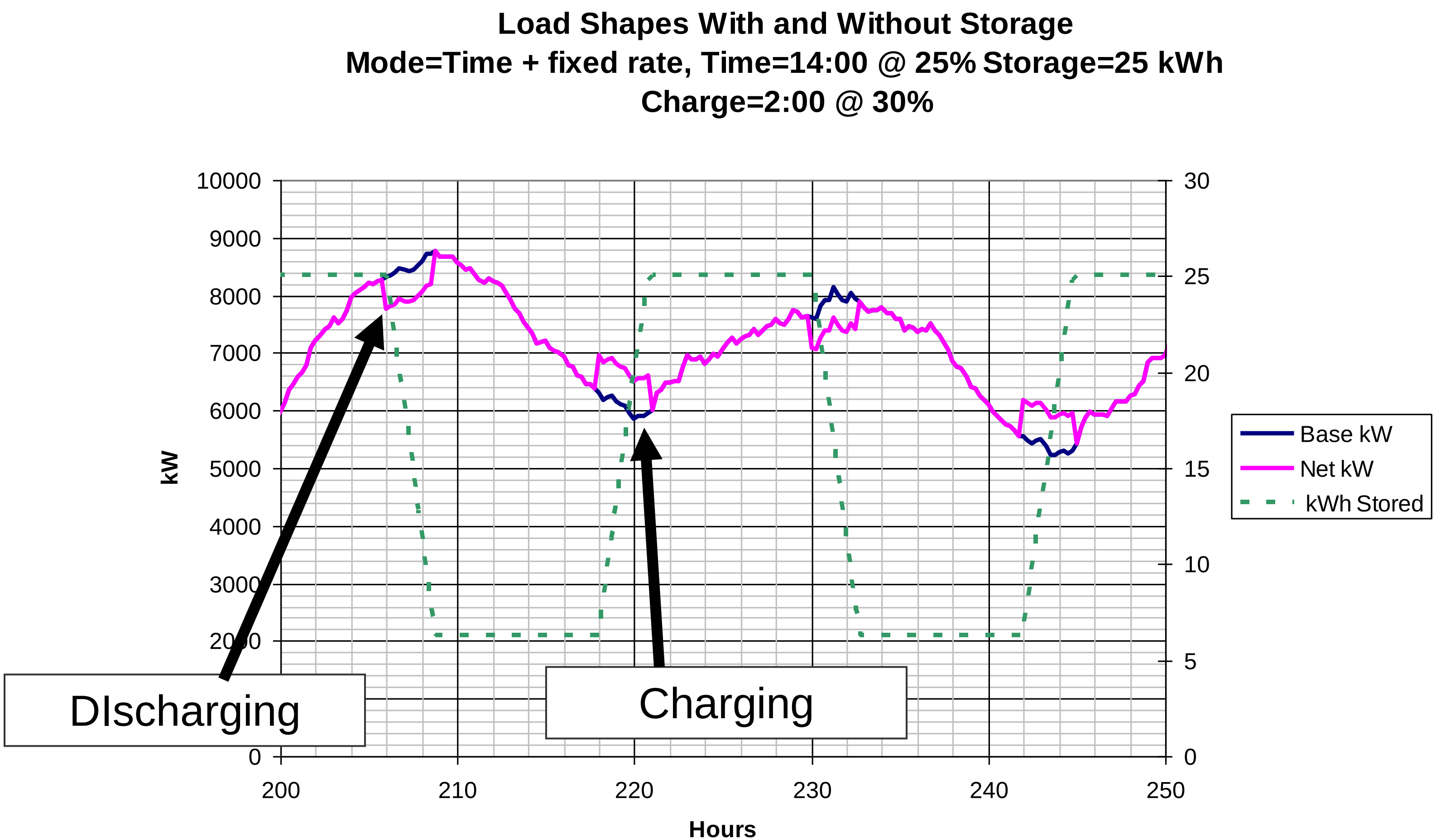
Simple Substation Peak Shaving



Attempting Peak Shave Every Day



Accounting for Storage Losses



Charging energy > Discharging energy (compare areas)

Key Distribution Modeling Capabilities for Smart Grid

- Distributed generation modeling
- Time series simulations
- Efficiency studies
- Meshed networks
- Large systems
- Parallel computing
- Distribution state estimation
- Protective relay simulation
- AMI Load data
- Modeling controllers
- Modeling comm
- Work flow integration

Key Challenges

- Merging Planning and Real-Time Analysis
- Very Large System Models
- Systems Communications Simulations
- Large Volume of AMI Data
- AMI-based Decision Making
- Time Series Simulations
- Distribution State Estimation

Key Challenges, Cont'd

- Detailed LV Modeling
- Including multiple feeders, transmission
- DG Integration and Protection
- Generator and Inverter Models
- Meshed (Looped) Network Systems
- Regulatory Time Pressures

Reference

- R.C. Dugan, R. F. Arritt, T. E. McDermott, S. M. Brahma, K. P. Schneider, “Distribution System Analysis To Support the Smart Grid”, presented at 2010 IEEE PES General Meeting, Minneapolis, MN

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