Coordinating Strategy for Integrating Electric Vehicles and Distributed Generation at High Penetrations

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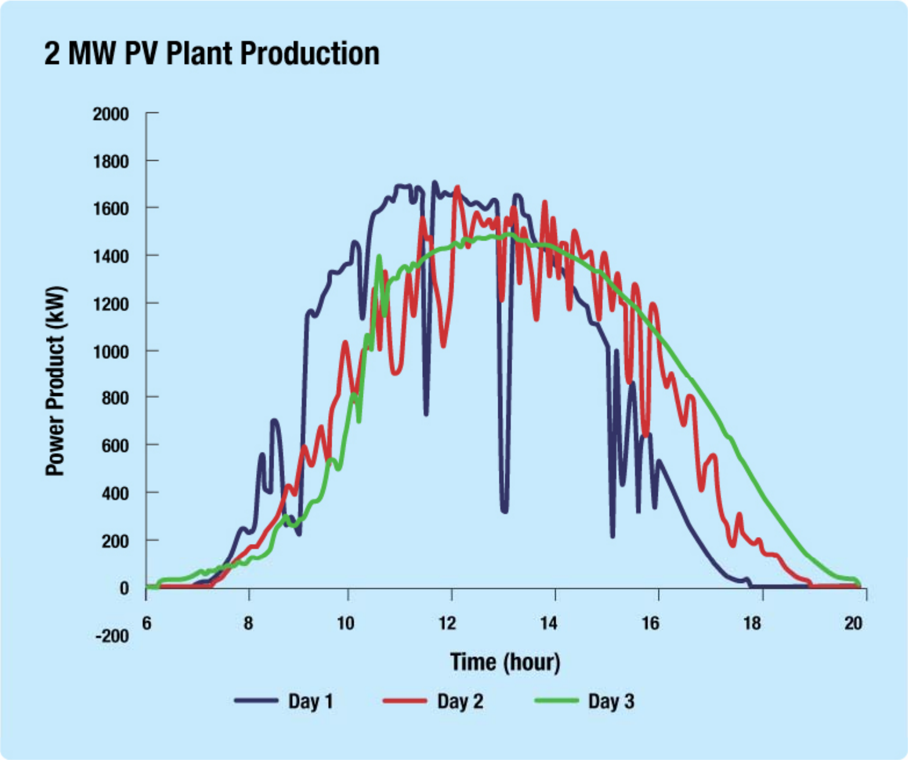
EV Integration Challenges

- On-peak uncontrolled charging
- Investment for Dist. & Tx
- Weak feeders with high penetration
- Uncoordinated planning
- No dispatch and V2G
- Lack of Distributed Storage
- Simplified charger control
  - No VAR, VR, VRT, etc.
- Limited modeling and forecasting

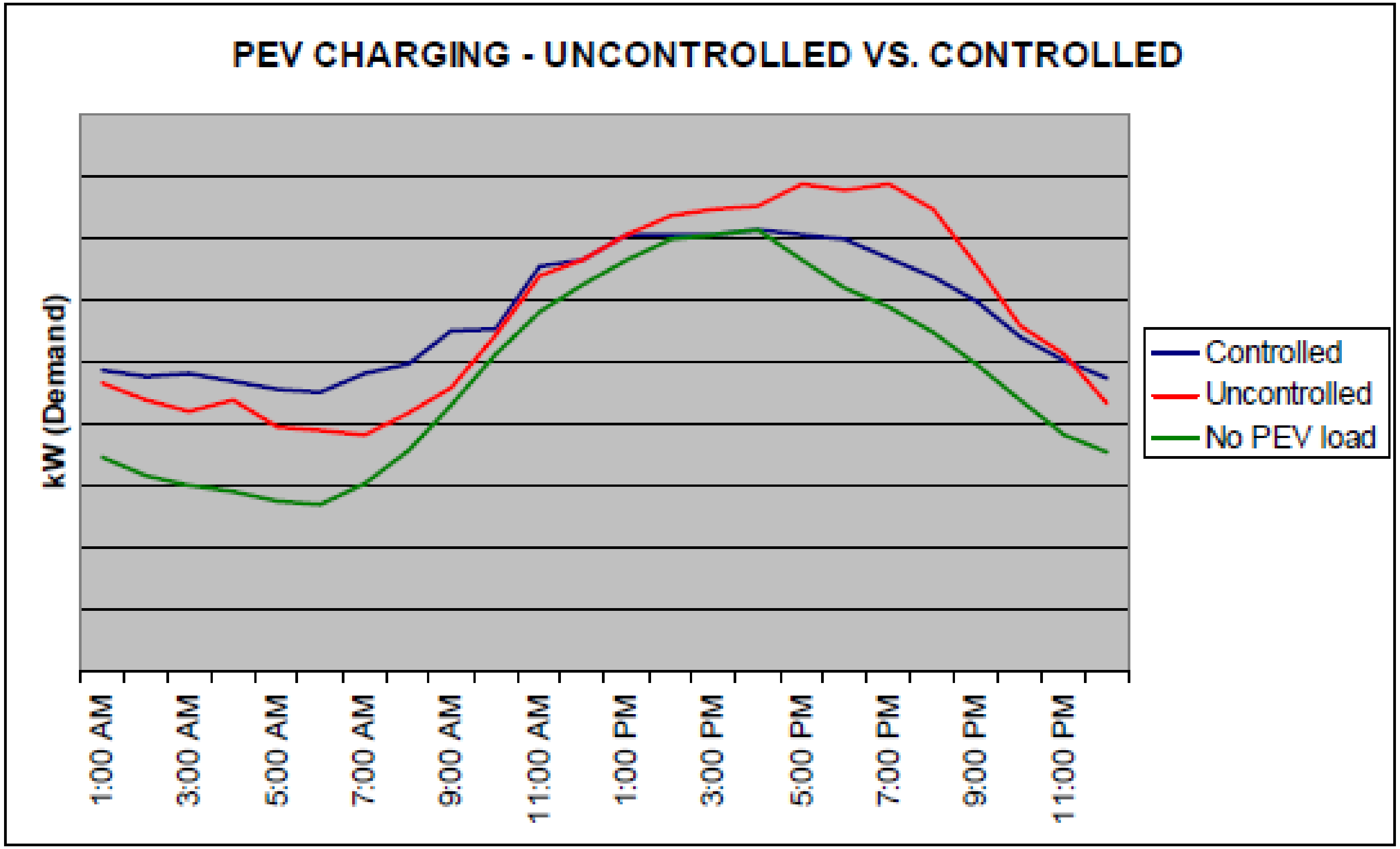
PV Integration Challenges

- Investment, permitting and ROW of T&D
- Weak feeders with high penetration
- Fast ramping requirements
- No dispatch and limited energy storage
- Intermittency of PV
- Simplified inverter control
  - No VRT, VAR, VR, etc.
- Off-peak generation
- Protection coordination
- Limited forecasting

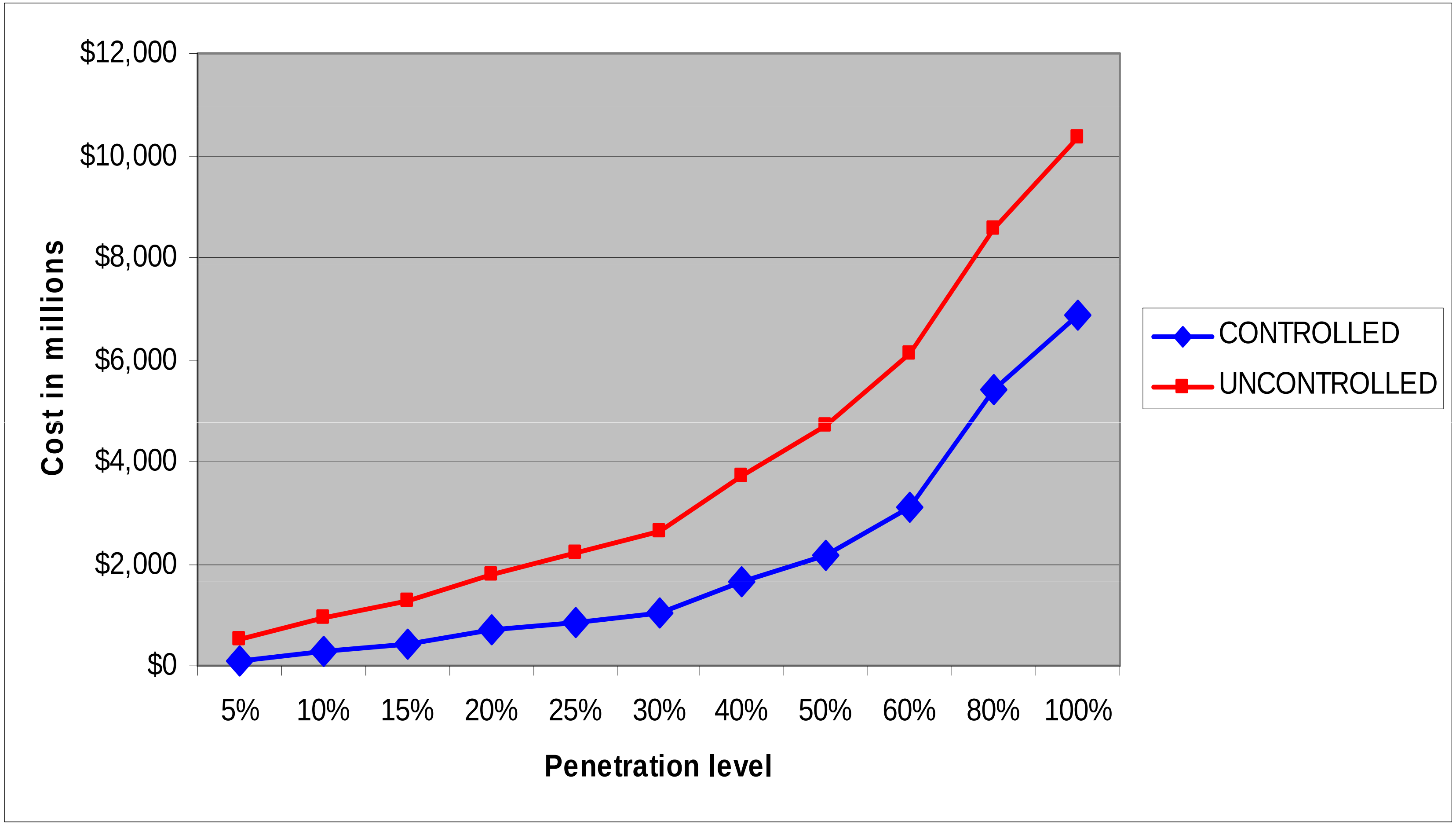


2 MW PV Solar generation profiles during 3 days in southern California

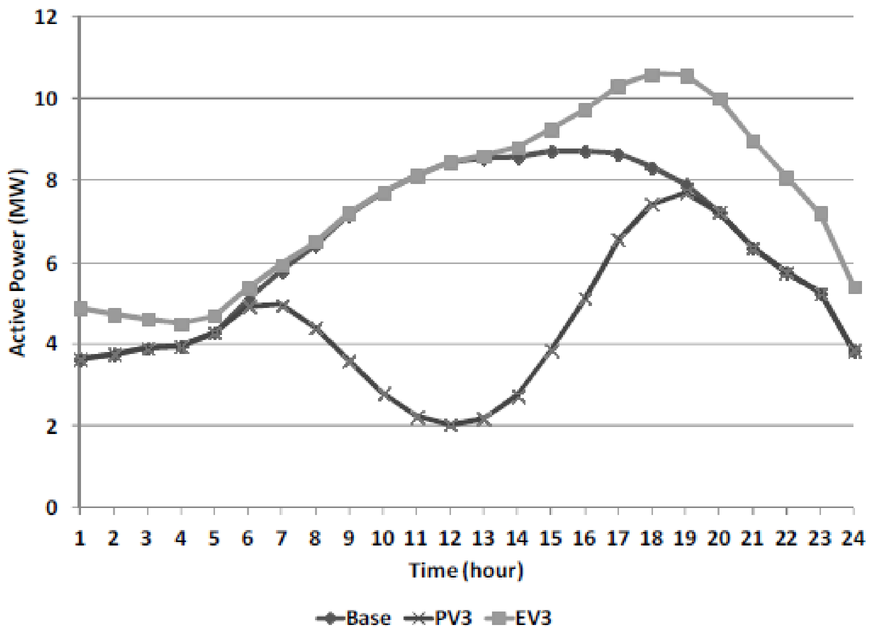
EV Impact Analysis – Load Curve

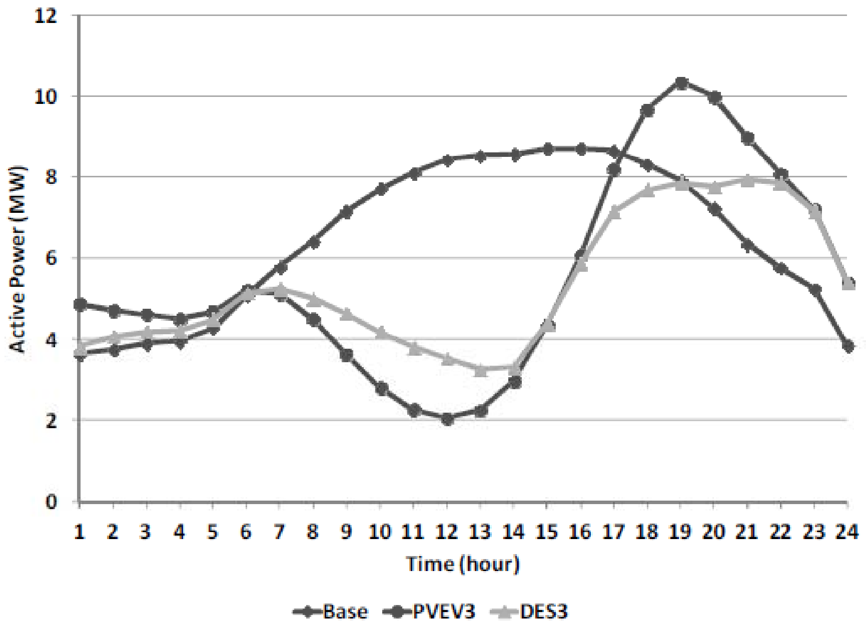


Cost Comparison



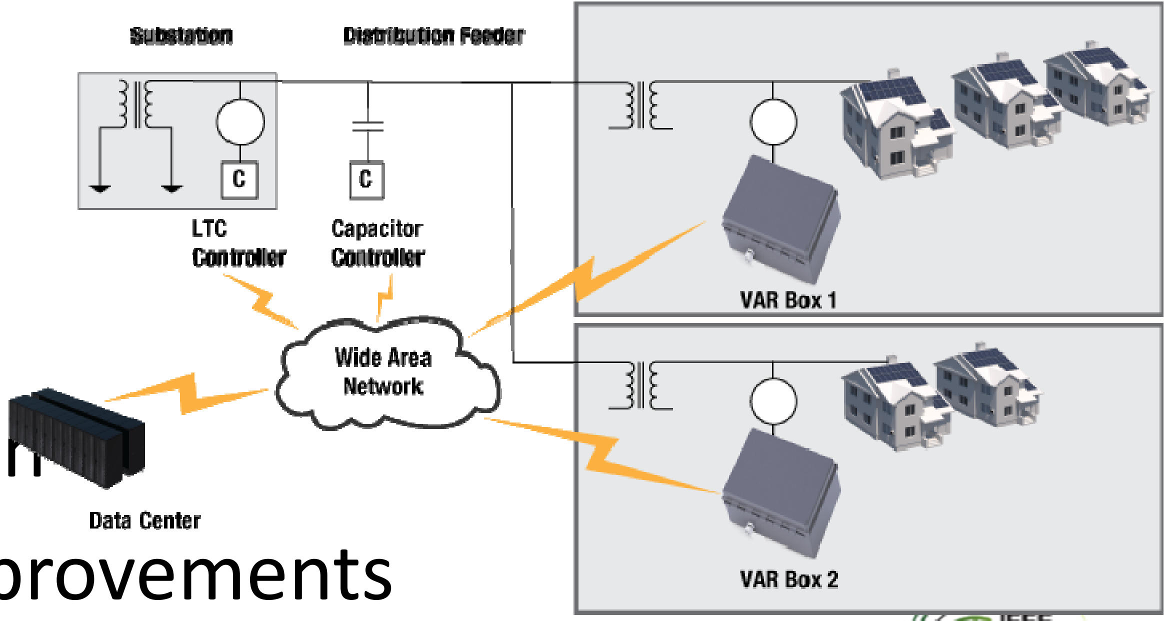
EV, PV and DES Integration



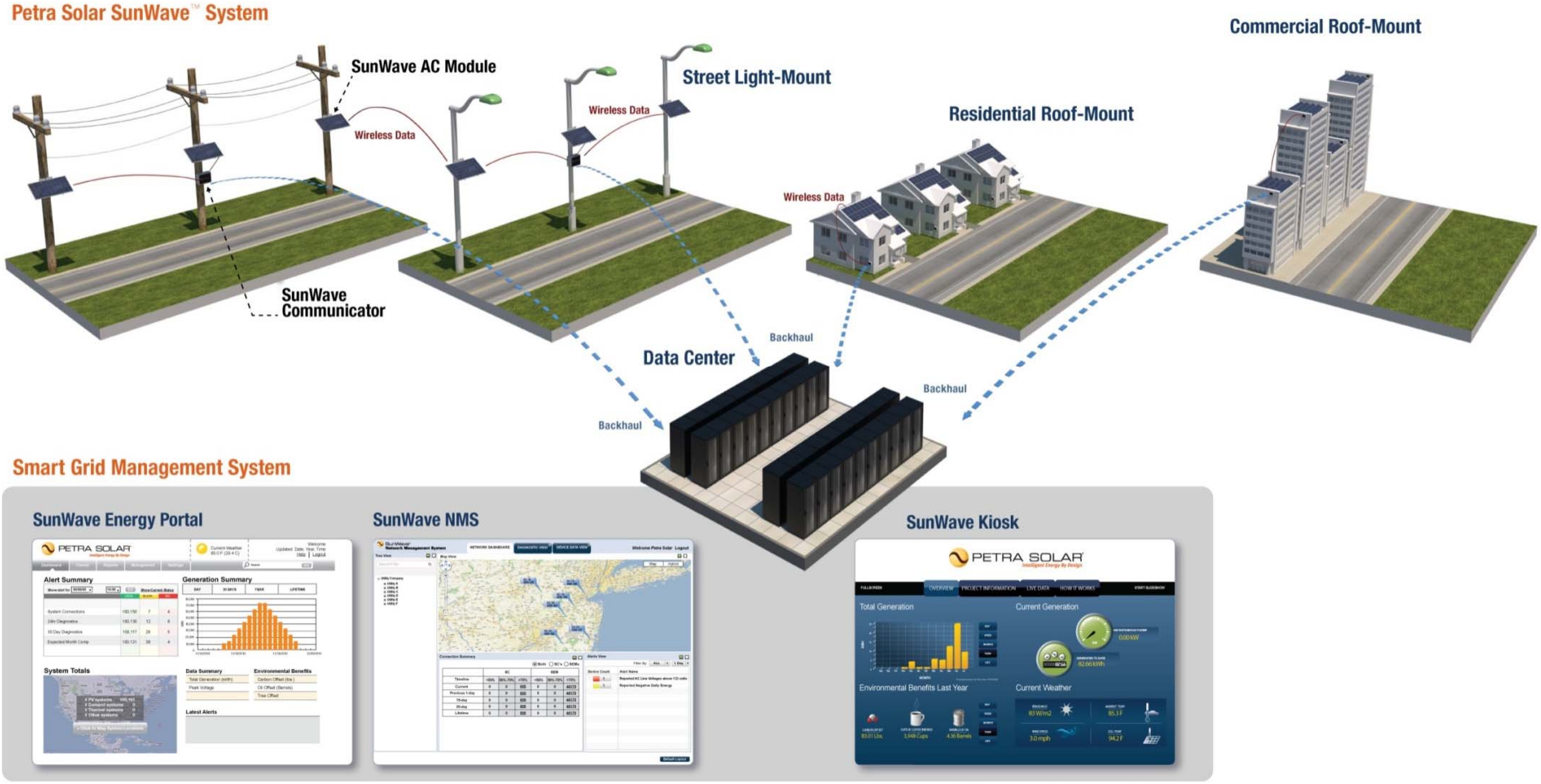


Coordinated Distributed Dynamic Volt-VAR Compensation

- Reduce T&D and transformer losses
- Capacity relieve and peakshaving
- Dynamic voltage ride-through and regulation
- Defer CAPEX
- Self-healing Dx
- EV Integration
- Storage Integration
- Power Quality Improvements



The Emerging Virtual Power Plant



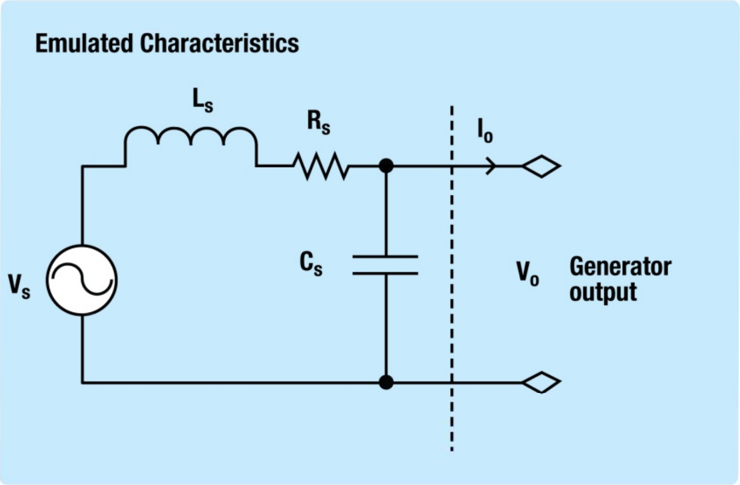
Advanced Generator Emulation Controls

Basic concept behind Generator Emulation Controls

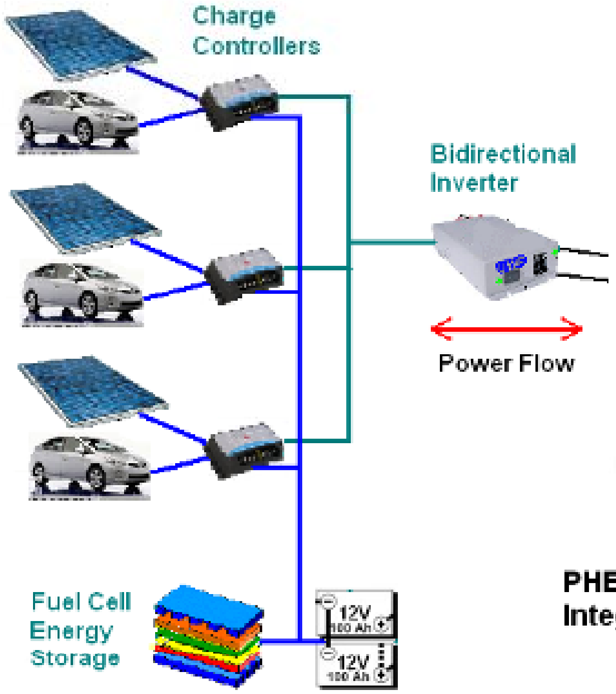
- Control PV inverters in a manner that emulates characteristics and behavior of traditional synchronous generators

GEC allows PV inverters to:

- Supply reactive power and active power filtering
- Support voltage stability through Volt/VAr control
- Perform voltage ride-through (VRT)



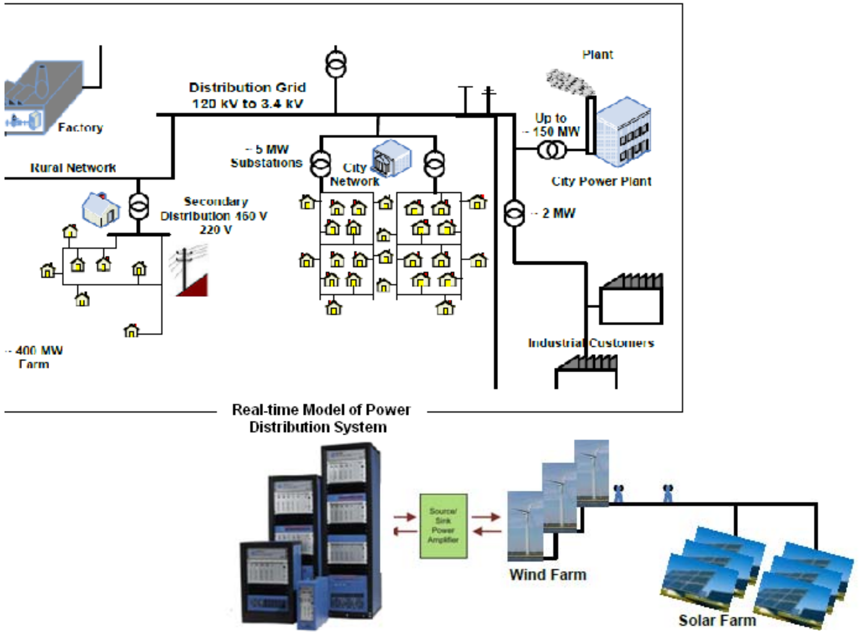
Real-time EV & PV Integration Analysis



PHEV-Grid Integration

Utilizes:
- **Load**
- **V2G**
- **DER modes**

Charging Station/ Energy Storage and Interconnection Studies



Renewable Energy Penetration and Grid Impact

Conclusion

- Mitigate integration challenges with coordinated DG (PV) integration and controlled EV charging
- Require V-Q regulation and VRT in Smarter PV inverters
- Coordinate DR (PV, EVs and Storage) with adequate communications into Virtual Power Plants (VPP) to improve system operations and dispatch
- Focus on (wireless) communication, interoperability and cyber security of VPPs
- Provide distributed (dynamic) reactive power for improved reliability in VPPs

Questions?

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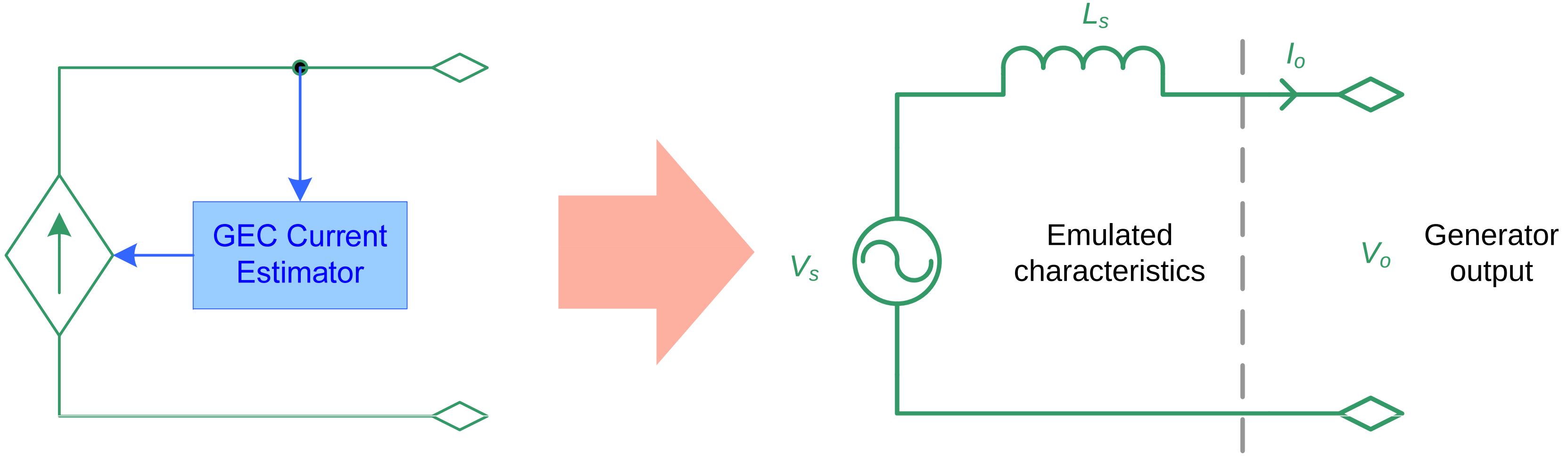
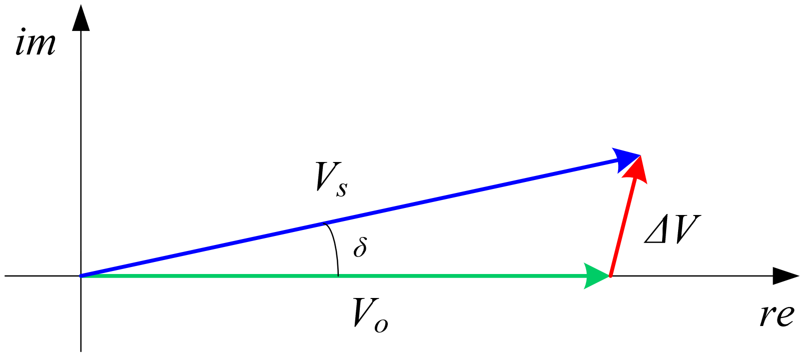
GEC Concept Overview



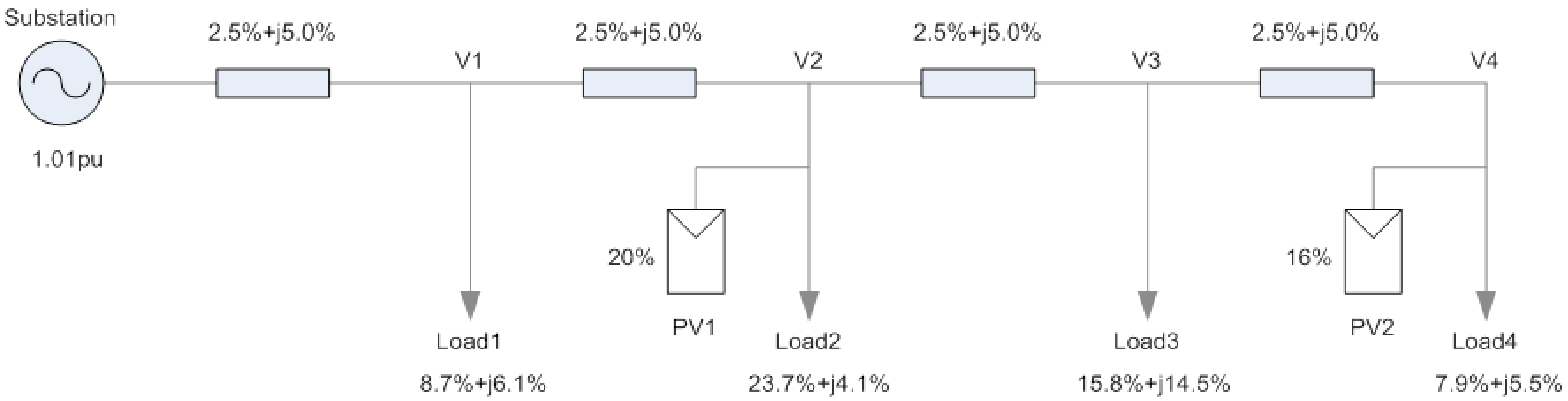


$$P_o \approx \frac{|V_o|\cdot|V_s|\cdot\delta}{\omega\cdot L_s}$$

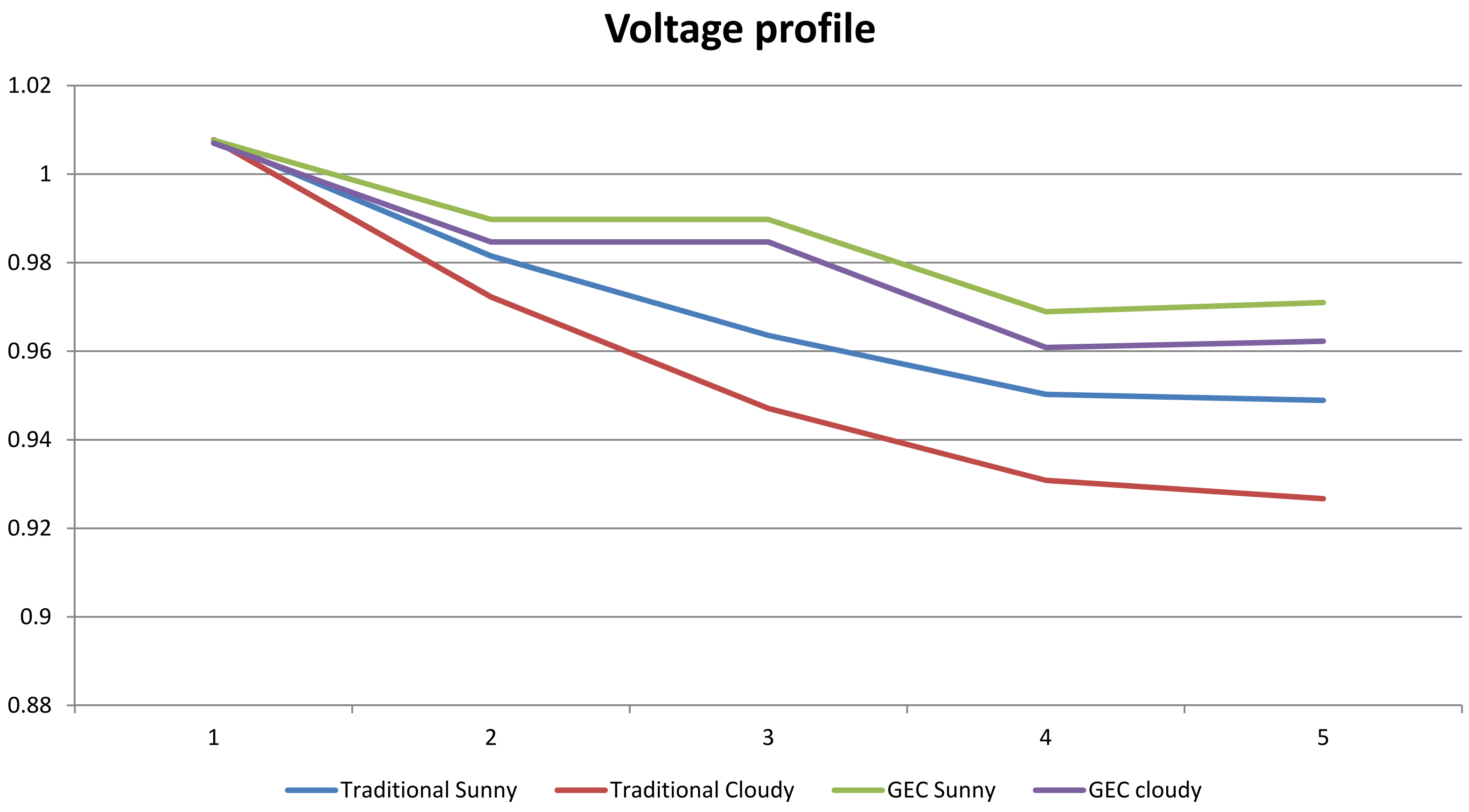
$$Q_o \approx \frac{|V_o|\cdot\left(|V_s|-|V_o|\right)}{\omega\cdot L_s}$$

Petra Solar - Case Study

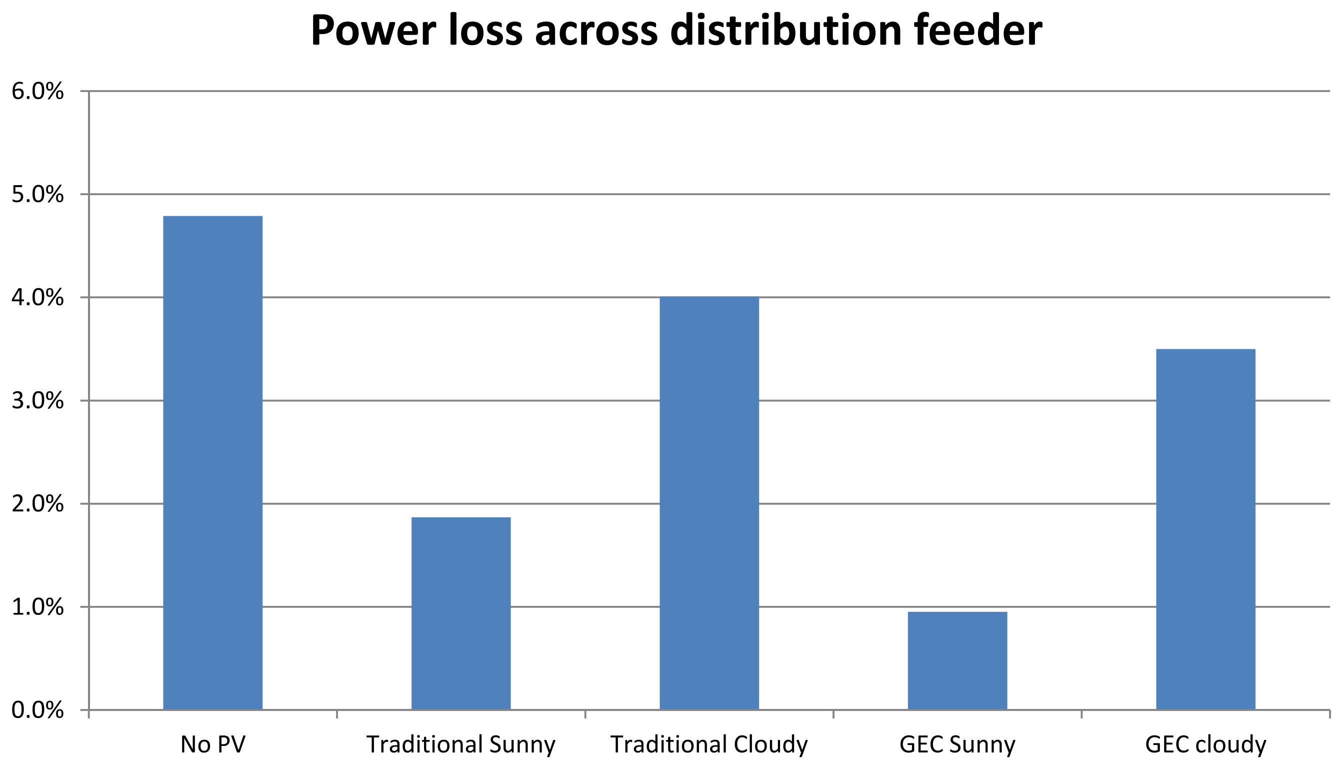
- 12kV, 10MVA feeder on a per unit basis
  - 68% load at 0.86 power factor
  - 36% PV penetration



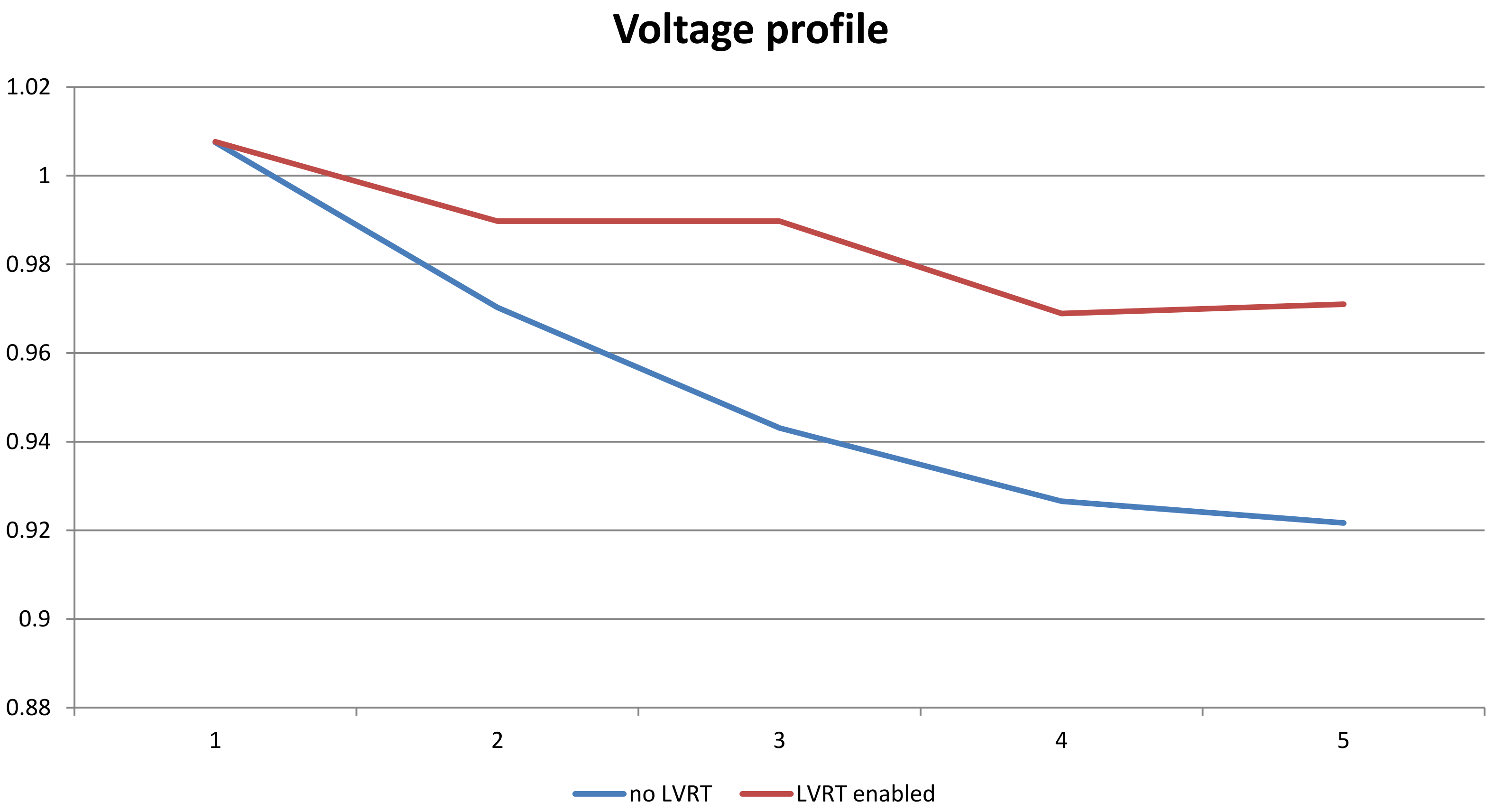
Response to Cloud Activity



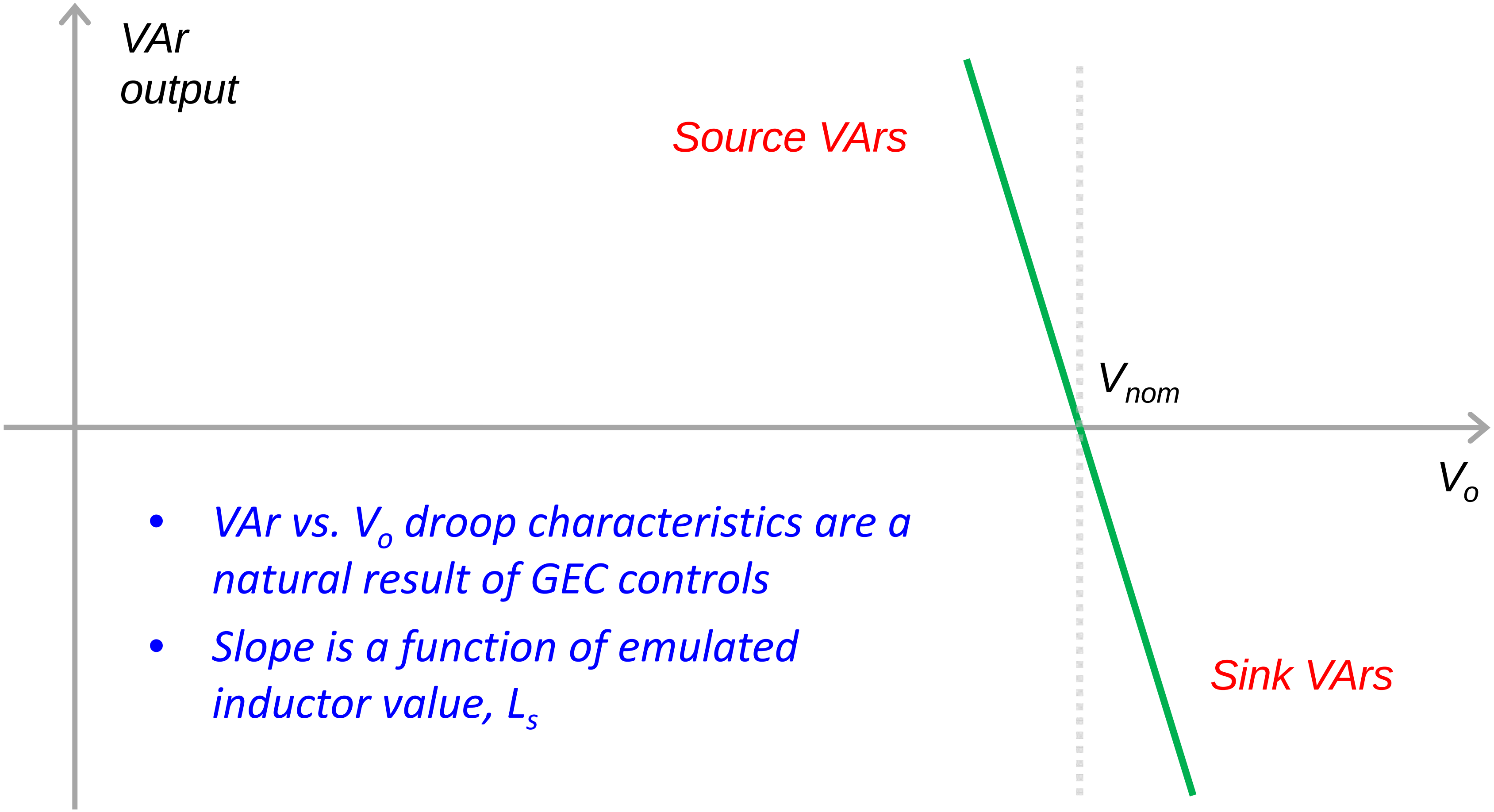
Distribution Power Loss



Voltage Response with LVRT

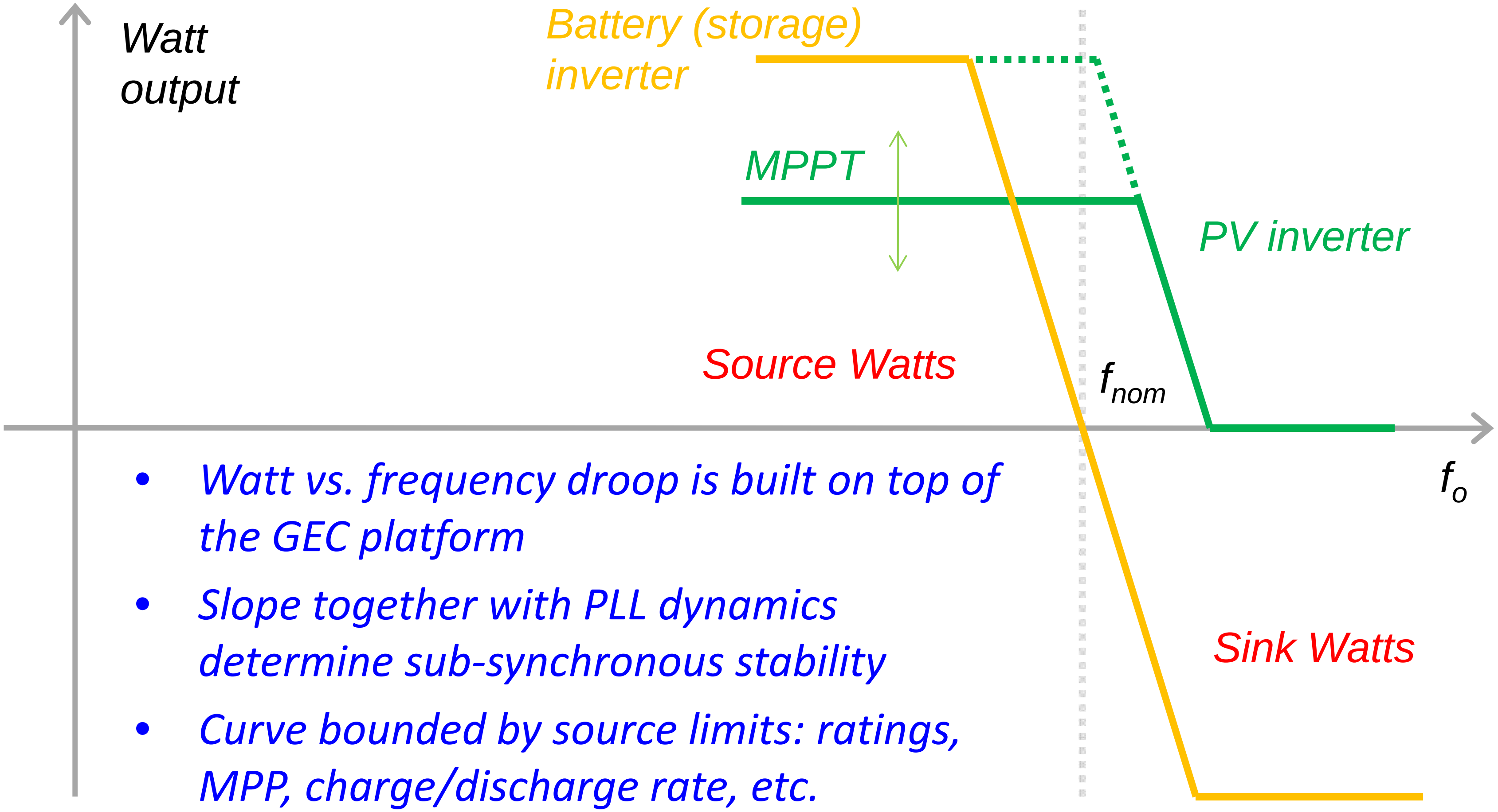


VAr Droop Characteristics



- *VAr vs. V_o droop characteristics are a natural result of GEC controls*
- *Slope is a function of emulated inductor value, L_s*

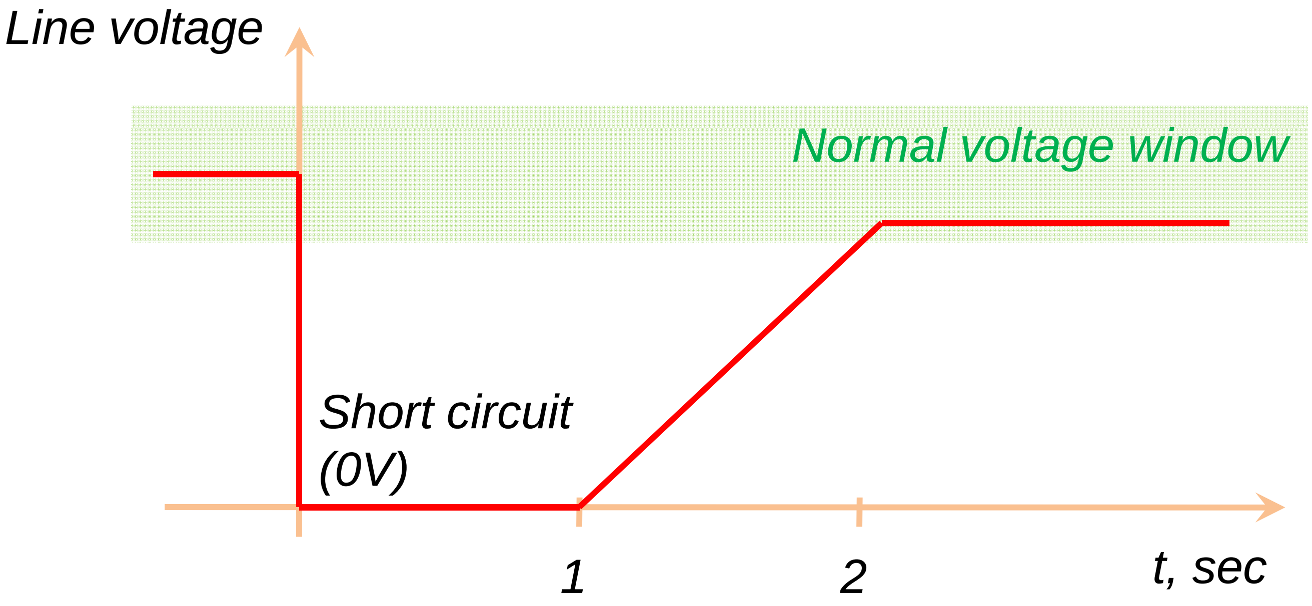
Watt Droop Characteristics



- *Watt vs. frequency droop is built on top of the GEC platform*
- *Slope together with PLL dynamics determine sub-synchronous stability*
- *Curve bounded by source limits: ratings, MPP, charge/discharge rate, etc.*

Low-Voltage Ride-Through

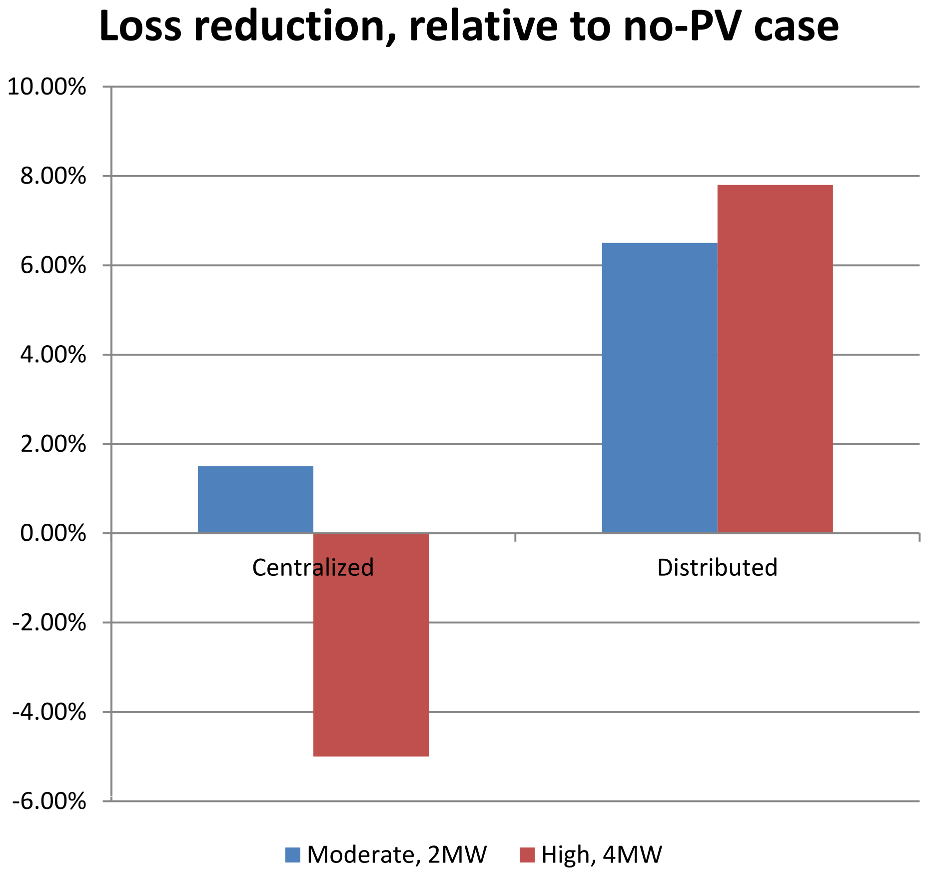
- Voltage ride-through prevents nuisance tripping
  - Mitigates voltage flicker due to disconnection and later reconnection
  - Avoids power loss associated with reconnection time



Feeder Study of High PV Penetration

- Quanta Technologies performed study on performance of a feeder circuit in Atlantic City Electric’s (ACE) territory
- Compared micro-scale vs. centralized PV
  - Power losses
  - Voltage violations
- Simulated
  - High and low penetration: 2MW and 4MW
  - Traditional vs. GEC

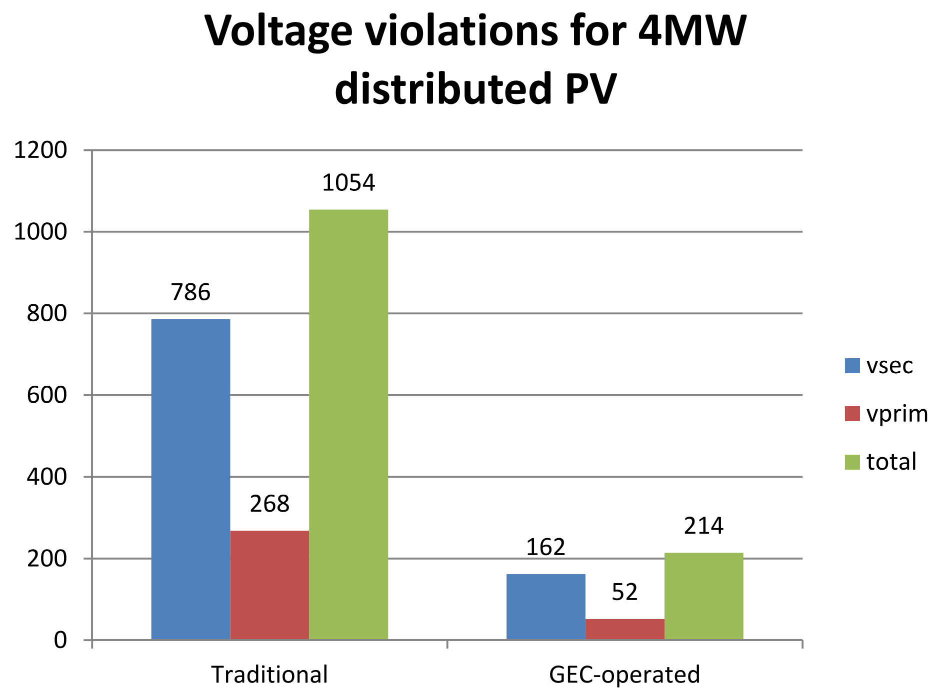
Average Losses Reduction



- The average loss reduction with respect to the base case (no PV-DG)
- Centralized PV leads to increased losses at high penetration due to increased circulation
- Distributed PV is effective in reducing power losses

Voltage Violations

- GEC is quite effective in reducing the number of voltage violations



DG PV Mitigation - Inverters

- PV Inverters with dynamic Volt - VAR regulation
  - Intelligent inverters mitigate voltage profiles
  - Minimize capacitor and VR switching
  - Voltage support to mitigate TOVs
  - Voltage regulation during solar clouded conditions
  - PV inverters and plants should provide LVRT
- Feeders with communication relays
- Control coordination of V-Q regulating devices
- Distributed Energy Storage and Dynamic VAr Regulation
  - Reliability during faults and switching
  - Support TOV during islanding and feeder switching
  - Dispatchable PV and Smoothing

Key Requirements for PV Integration

- Validate and test PV inverter and system models
- Robust Distribution Automation and communications
- Automated system operation of µGrids
- Dispatchable Virtual PV Power Plants with storage
- Coordinated dynamic VAR management
- PV inverters provide Volt – VAR regulation
- Improved (anti-)islanding controls
- Protection coordination in µGrids
- Revenue models for operators

Technical Requirements for DG-PV

- Highly Distributed Generation
  - No increase in T&D capacity requirements
  - Minimal permitting requirements – Fast deployment
- Dispatchable Solar PV
  - Mitigating PV intermittency using dynamic reactive power
  - Small distributed energy storage with DR
  - Smart Inverters – LVRT; P-Q; V-reg.; ramping
  - Mimic generator operation
- Smart Grid Enabled
  - Communication network integration
  - Remote sensing of grid and production
  - Demand Response and V-Q Optimization
- Enterprise Integration
  - Distribution automation – Virtual Power Plants
  - Enhanced cyber security