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AE Solar Energy

TRANSFORMING DISTRIBUTED SOLAR

Presentation Overview

- Advanced Energy
- Problem Statement
- Research Focus Areas
- Demonstrations and Results
- Program Outcomes
- Future Work / Conclusions

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

SEL SCHWEITZER ENGINEERING LABORATORIES, INC.

PGE Portland General Electric

pepco

NPPT

SunShot U.S. Department of Energy

GO solar CALIFORNIA

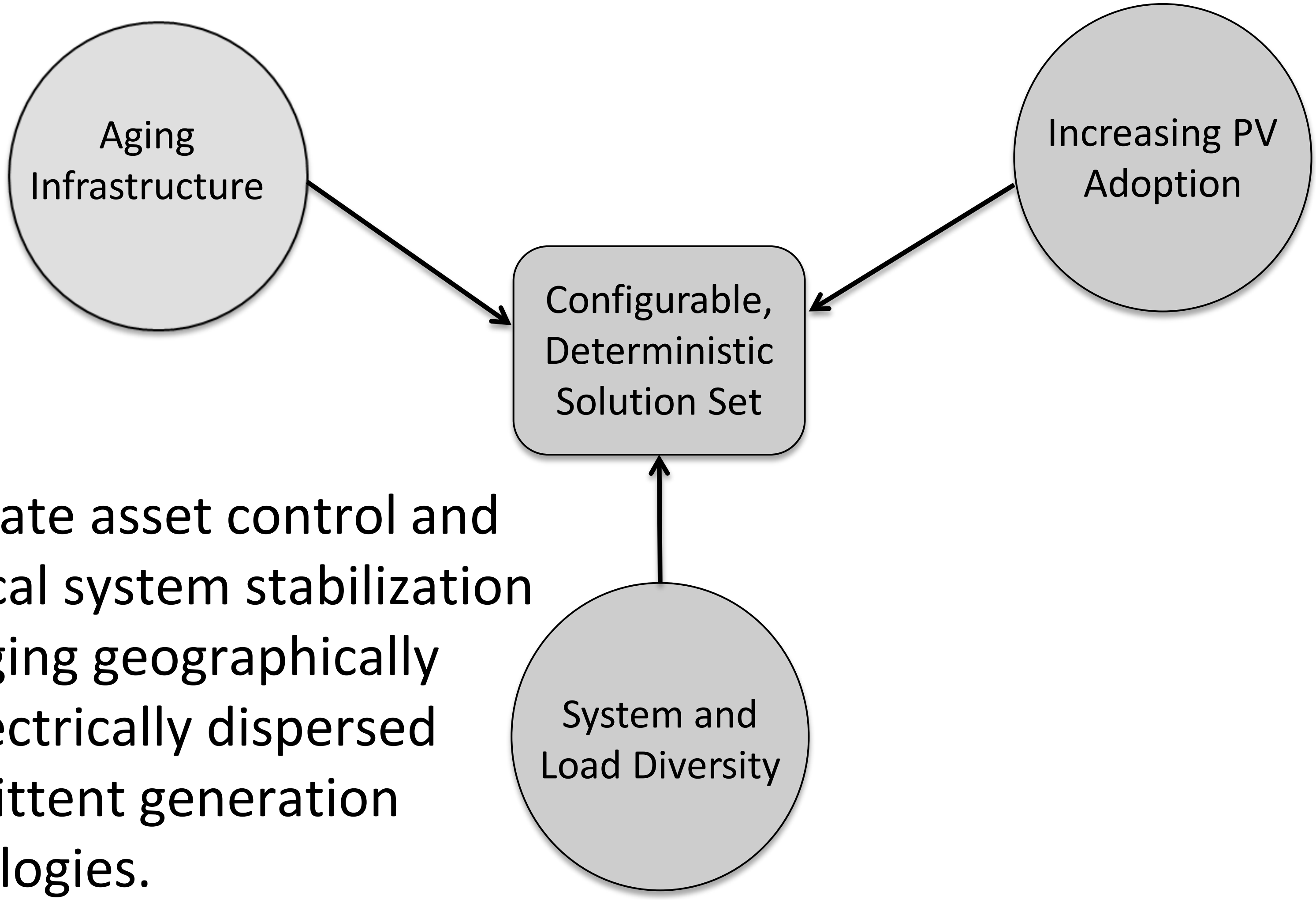
Advanced Energy Overview

- 30-Year Focus on Power Conversion Solutions
  - Founded in 1981 in Ft. Collins Colorado
  - 4 major sites (Ft. Collins, Bend, Toronto, Shenzhen)
  - 1471 Employees worldwide
  - Dedicated service organization
- Two Business Units
  - AE Thin Films: Power conversion solutions for thin-film plasma manufacturing
  - AE Solar Energy: PV inverters and energy management solutions
- Solid Footing in Growing Solar Inverter Market
  - Leadership in North America
  - Customer focused

AE Solar Energy Markets

Solar PV power conversion and architecture solutions aimed at lowest cost of energy through project life-cycle

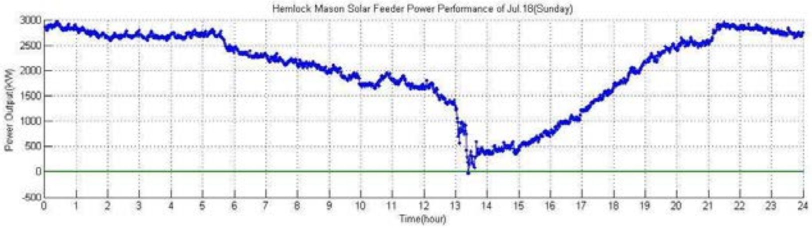
AE Led SEGIS-AC Program Addresses

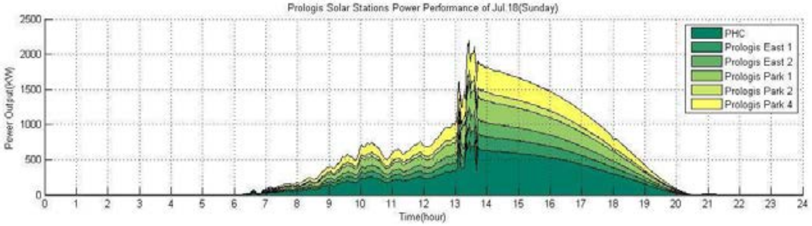


- Aggregate asset control and electrical system stabilization leveraging geographically and electrically dispersed intermittent generation technologies.

Program Approach

- SEGIS-AC Phase I
  - > Technology development
  - > Lab Validation (NREL ESIF)
- SEGIS-AC Phase II
  - > Demonstration period
  - > Value of VAr's
  - > Aggregate response
- Program Diversity
  - > East / West Coast
  - > Feeder selection
  - > Utility control strategies





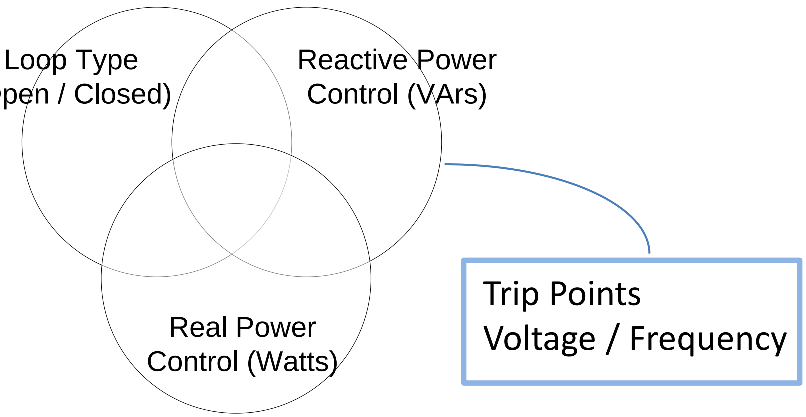
Program Specific Demonstration Topics

- User Configurable Voltage and Frequency Support Functions
  - > Interconnection guidelines
  - > System impacts and equipment preservation
- Optimized Storage Integration for Ramp Rate Mitigation
  - > Intermittency reduction
  - > Electro-mechanical voltage regulator bridge
- Island Detection Strategy for Clustered Generation Assets
  - > Effective, Safe, Deterministic
  - > Works in concert with Voltage and Frequency support functions

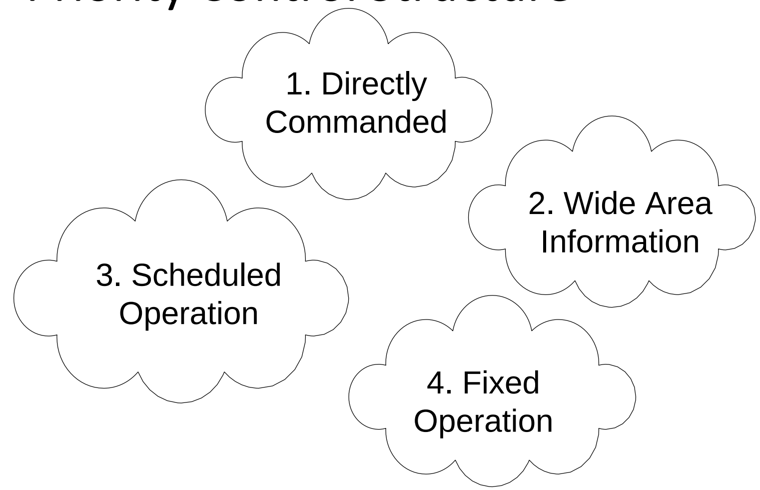
* *Grid integration, Interconnection, and Accurate Modeling tools are primary target areas for the Research and Demonstrations of these technologies*

Voltage / Frequency Support Functions

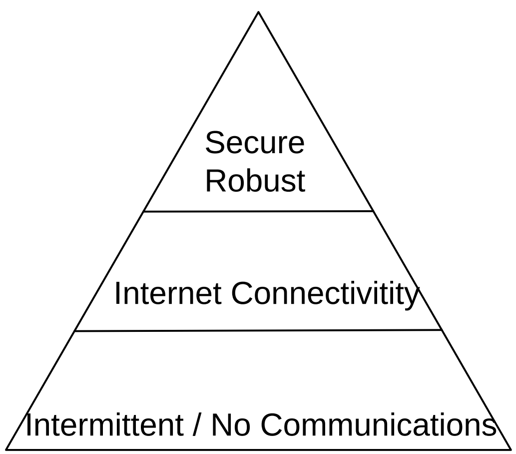
- Voltage Support Functions



- Priority Control Structure



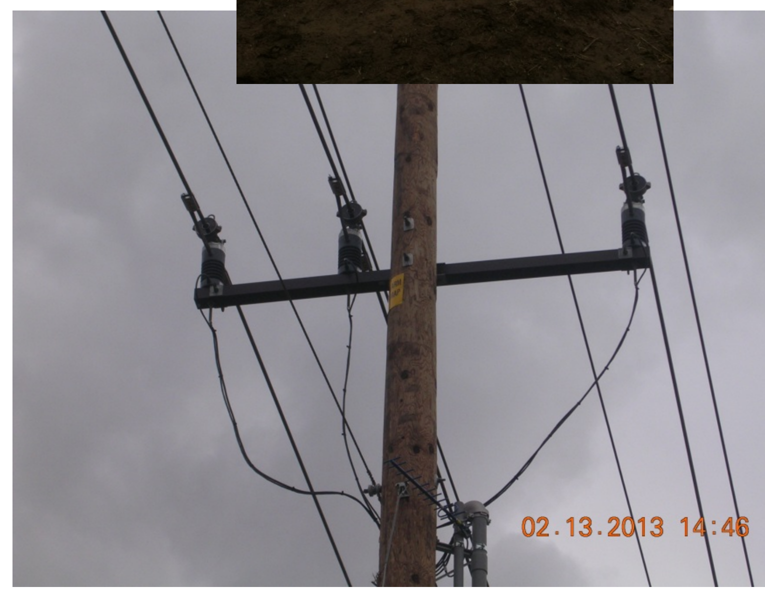
- Degree of Communications



- Management / Configuration Tools
  - Deterministic
  - User configurable
  - Authentication and authorization
  - IMC vs. Stand-alone

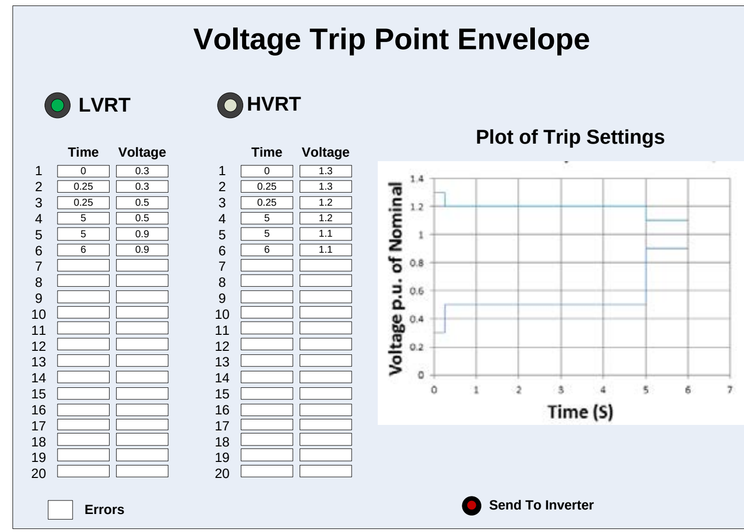
Voltage Support Demonstration and Analysis

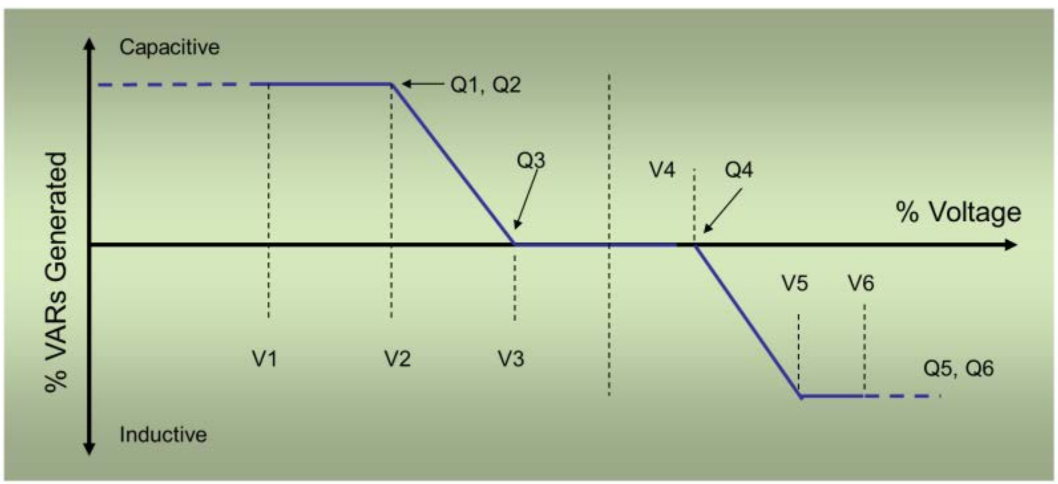
- Model Feeder Performance
  - > Regulator operations
  - > Cap bank switching events
  - > Optimize Volt/VAr profiles for feeder benefit
- Base-Line Feeder Operation and Performance
  - > Physically instrument feeder and collect 20 hz and 1 hz data (PMU w / GPS timestamp)
  - > Compare to model for validation purposes



Voltage Support Demonstration and Analysis (cont.)

- Enable Voltage Control Functions on PV Systems
  - Volt/VAr, Watt/Frequency, Volt/Watt (EPRI, 1547.8)
  - Monitor feeder performance (including regulator cycling events)
  - Optimize system leveraging peer communications (remote location)
- Document System Benefits / Drawbacks
  - Loss of power production
  - Improvement in system voltage stability
  - Improvement in electromechanical longevity

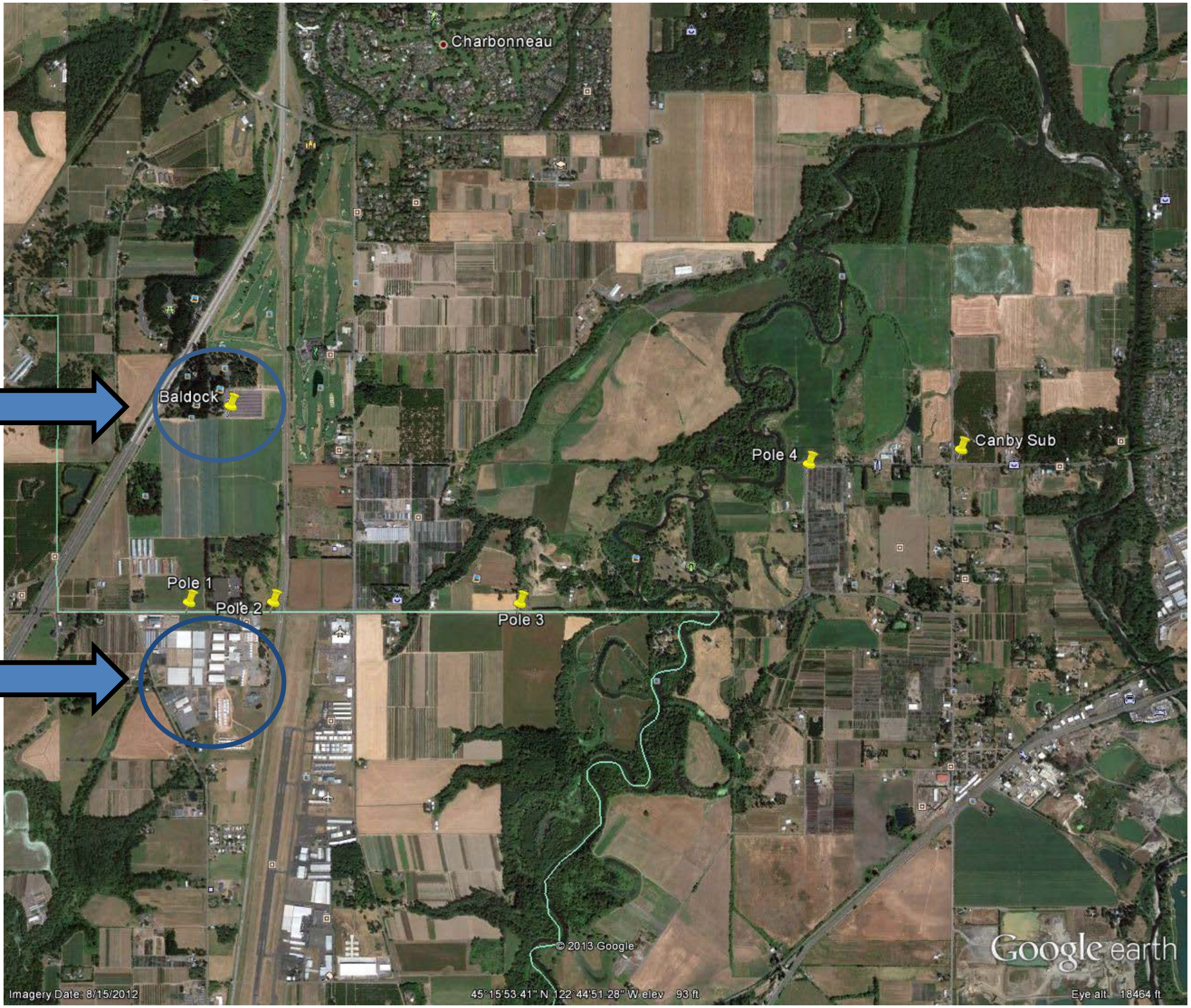




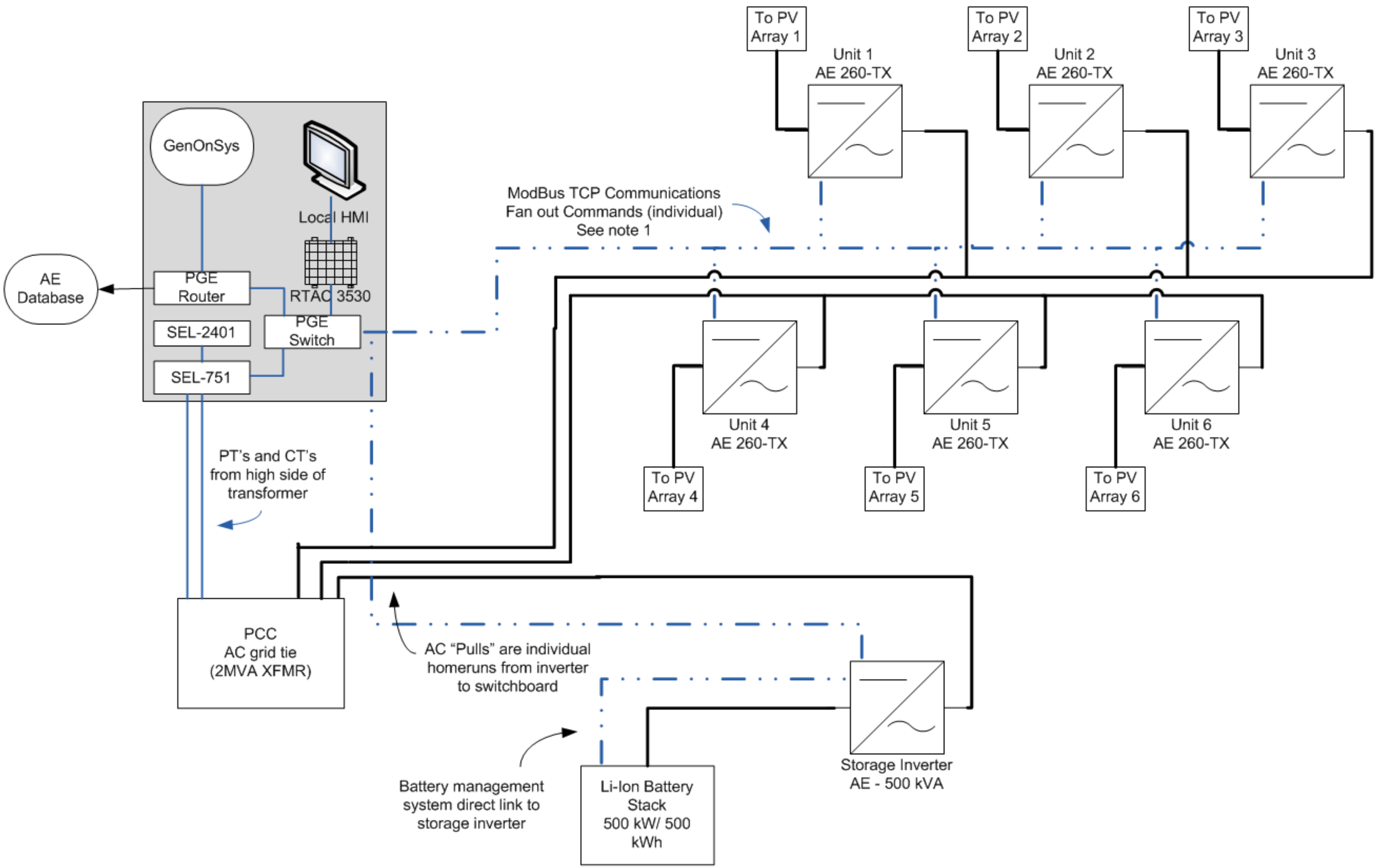
PMU and Metering Locations

PV Site “Baldock” (End of Circuit)

Large Induction Motor Loads (Compactors)

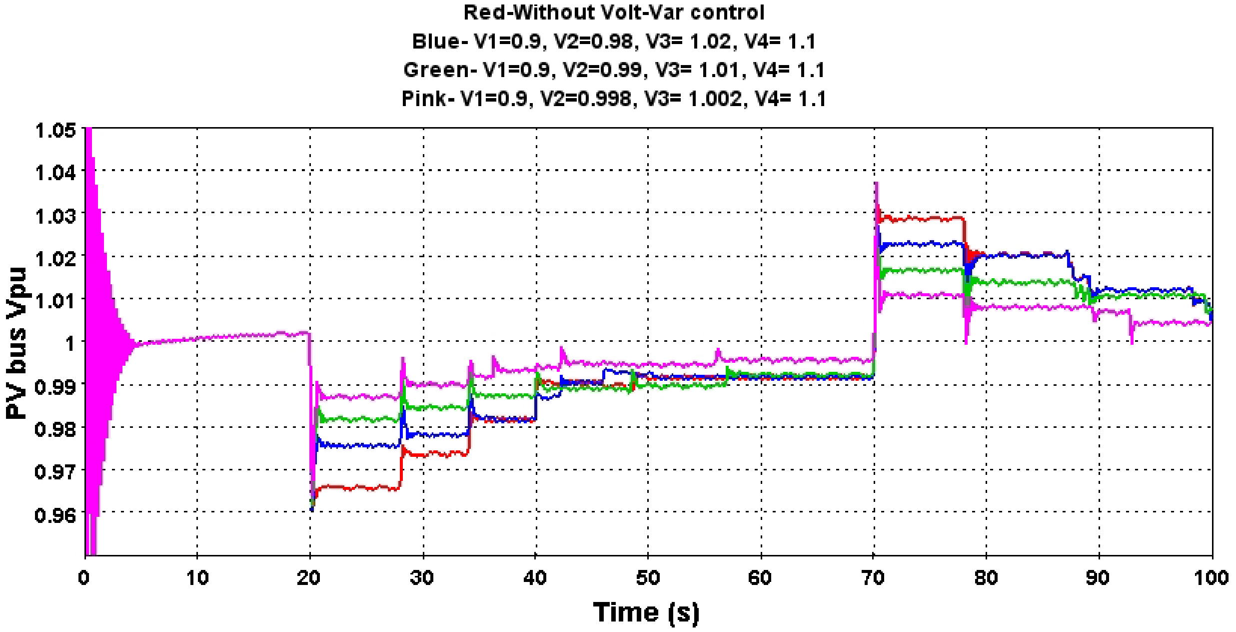


Baldock Solar Facility (West Coast Test Site #1)

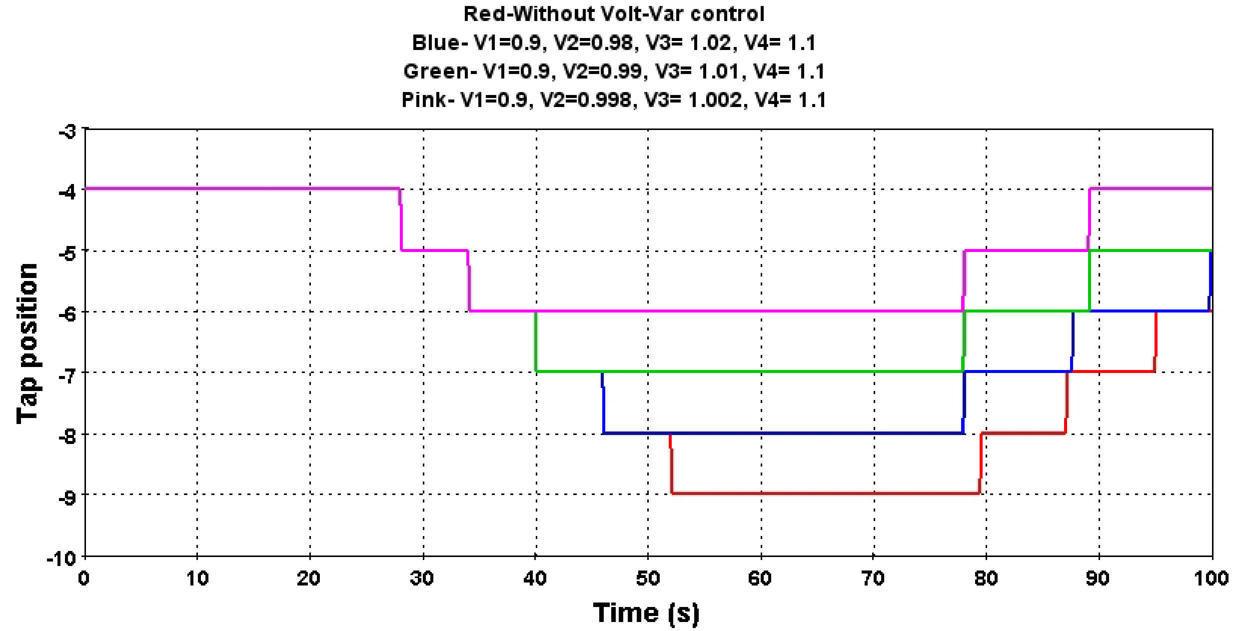


Motor Start Event

Improvement in POI voltage at the PV facility

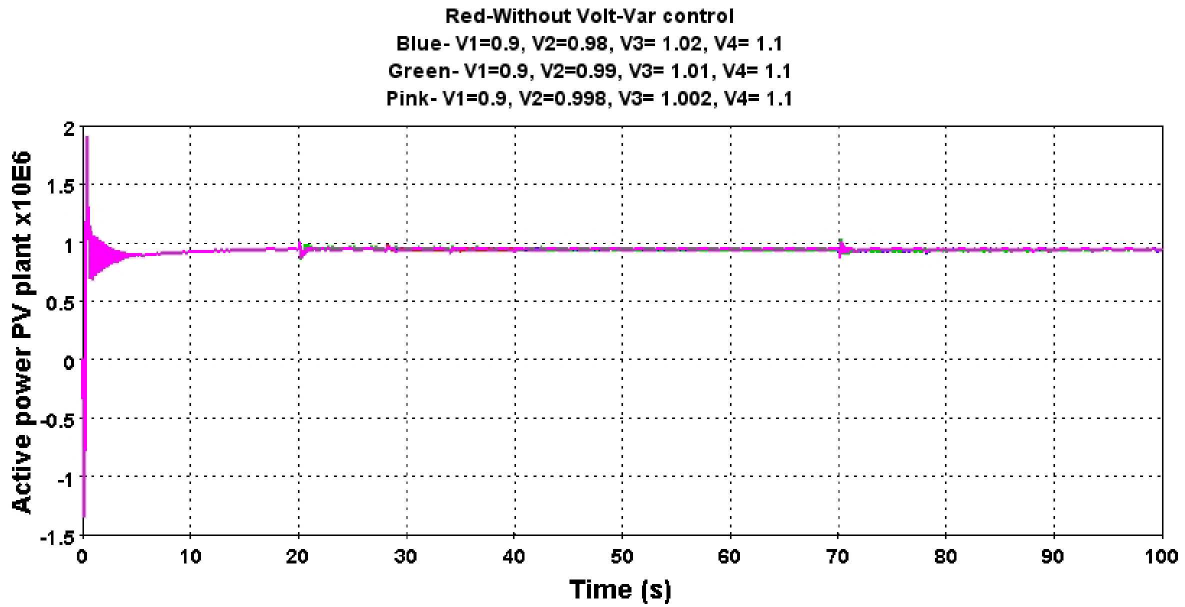


Reduction of Tap changes under motor start event

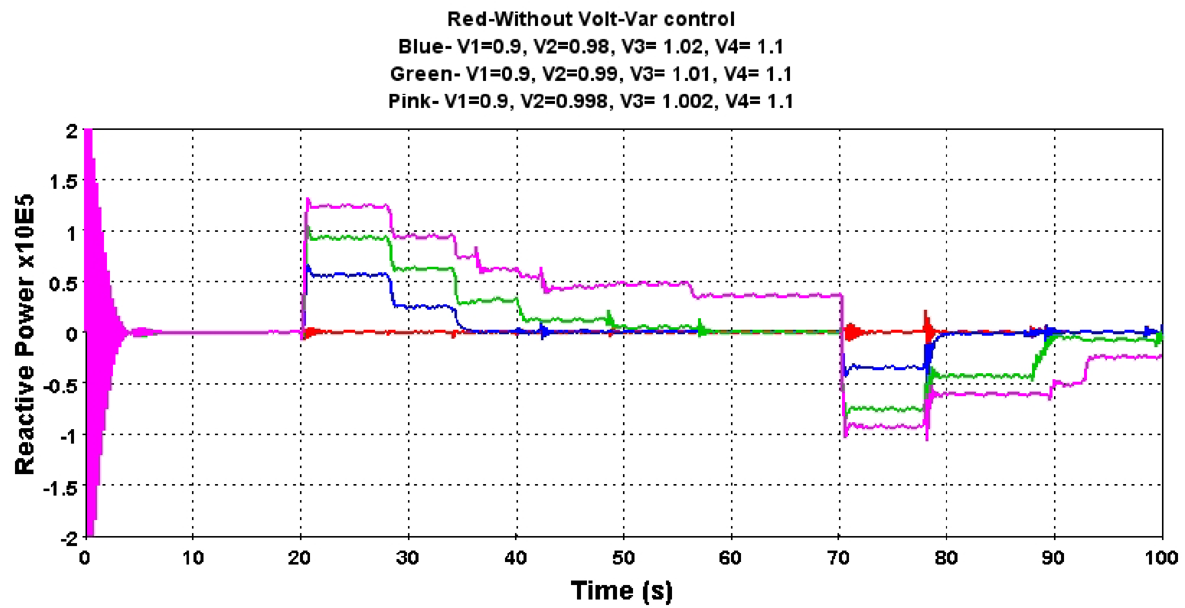


Motor Start Event

No loss of real power (all PV energy harvested)

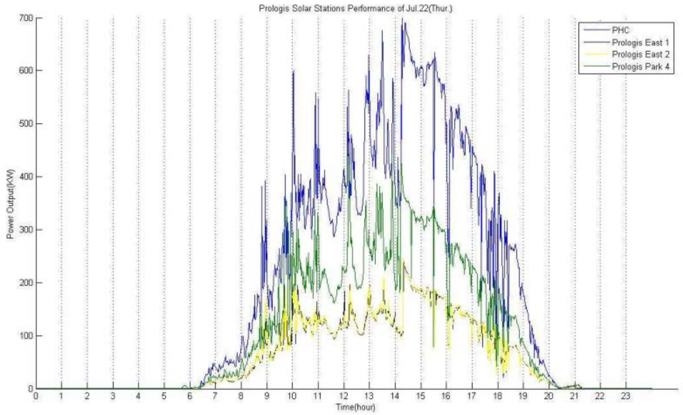


Reactive power from combined PV plant



Storage Integration Demonstration and Analysis

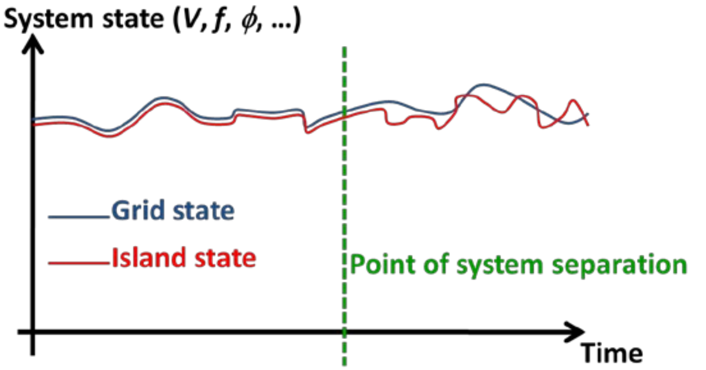
- Reduction of Cloud Induced Intermittency Effects
  - > Ramp Rate Control
  - > Power Battery
- Plant Level Response
  - > Focused on POI control
  - > “Surge” functionality

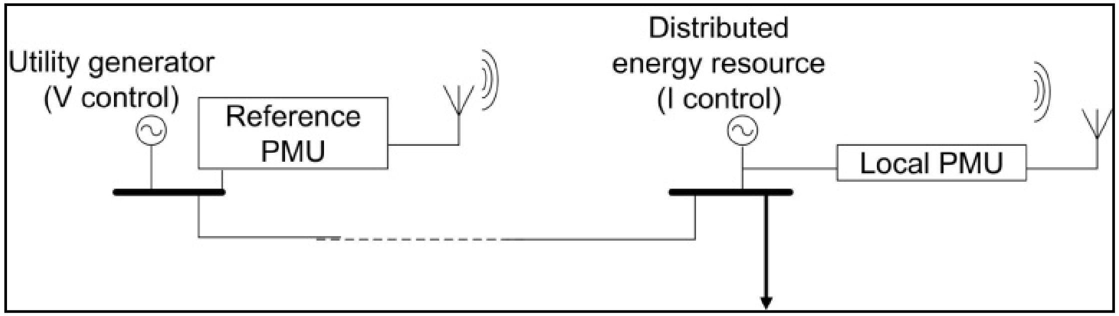


- Economic Value Model for Integrated Storage
  - > Develop economic model for lifetime cost / benefit
  - > Develop system sizing model for grid integration

Island Detection for High Penetration PV

- Alternative Strategy to Transfer Trip
  - > Additional feeder information / benefits
  - > Wide area impact / feedback
- Integrated Solution (POI)
  - > Enables voltage control functionality
  - > Communications agnostic approach





Island Detection Demonstration and Analysis

- Implement CCB Island Detection Algorithm at Sites
  - Reference PMU to be at substation
  - 900 MHz radio to sites
- Monitor Performance Over Demonstration Period
  - False trip immunity
  - Voltage control validation
- Validate Timing, Communications, and Implementation
  - Document performance over host of communication media
  - Latency, bit-error-rate, control zones
  - Harden "product" through rigorous testing

Expected Outcomes of Program

- Diverse understanding of practical voltage support functions implemented in distribution circuit connected PV sites.
  - > Voltage regulation cycle count reductions
  - > Improvement in voltage stability
- Documented performance of CCB island detection strategy in conjunction with voltage support functions.
  - > Alternative to XFER trip
  - > Economics associated with safety critical control
- Economic and performance model for storage based solutions to mitigate cloud induced intermittency
  - > Improvement in voltage quality
  - > Reduction of regulator cycles

Future Work

- Feeder Response to Volt / VAr controls
  - > Monitor active performance
  - > State initiation counts (how often)
  - > Engage wide area controls (PMU-based)
- Feeder Response to Ramp Rate Controller
  - > Electro-mechanical VR equipment response
  - > Firming and aggregation impacts to DSG group (PGE)
- Island Detection Reliability and Capability
  - > False trip immunity
  - > Correlation threshold monitoring
  - > State activation
- Publish Results

Conclusions

- VAr and Watt Impact Studies (Diverse Electrical Installations)
  - Categorize benefits of each separately
  - Categorize benefits of combined solutions
  - Investigate peer control using wide-area information
- Creation of User Configurable Profiles
  - Flexibility in installation needs
  - Tune to meet evolving needs of utility
  - Adjustable to meet forecasting and future modifications
- Economic Analysis
  - Storage integration
  - VAr support
  - System costs (longevity of existing equipment, feeder efficiency, total system loss)

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Q &A AND DISCUSSION