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Looking Ahead – EPRI R&D – Advanced Technologies to Manage and Integrate Distributed PV

Aminul Huque, Ph.D.

Sr. Project Engineer, Integration of Distributed Renewables, EPRI

Workshop on Achieving High Penetrations of PV

Solar Power International, September 14, 2012

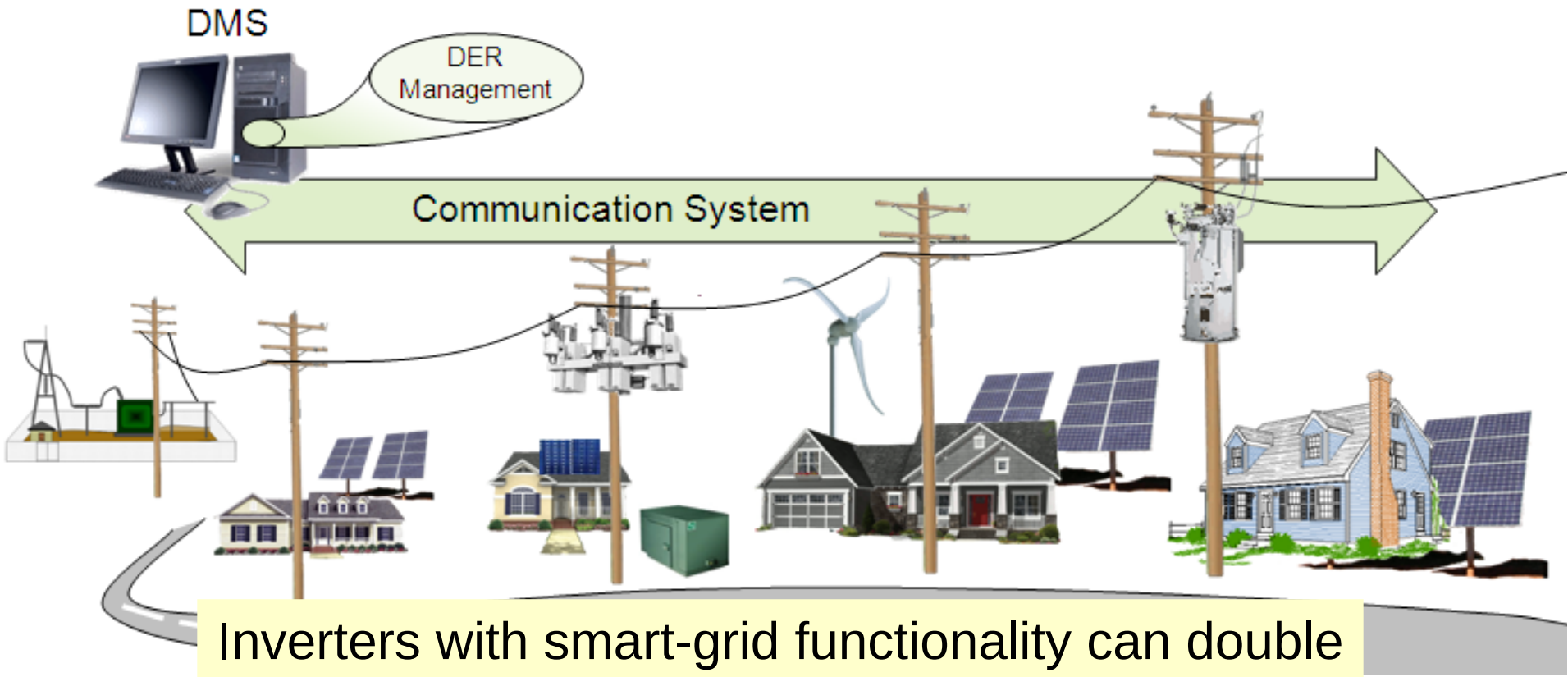
Inverter – Role in PV Plants?

PV inverter converts DC energy from solar modules in to AC energy and interface the PV system with electricity grid

Inverter Functionality Today	What it Can Do Tomorrow ?
• Harvesting maximum power from PV array • Matching plant output with grid voltage and frequency • Providing safety by providing unintentional islanding protection	• Providing grid-support for stability • Improving PV system reliability • Reducing PV Balance of Plant Cost

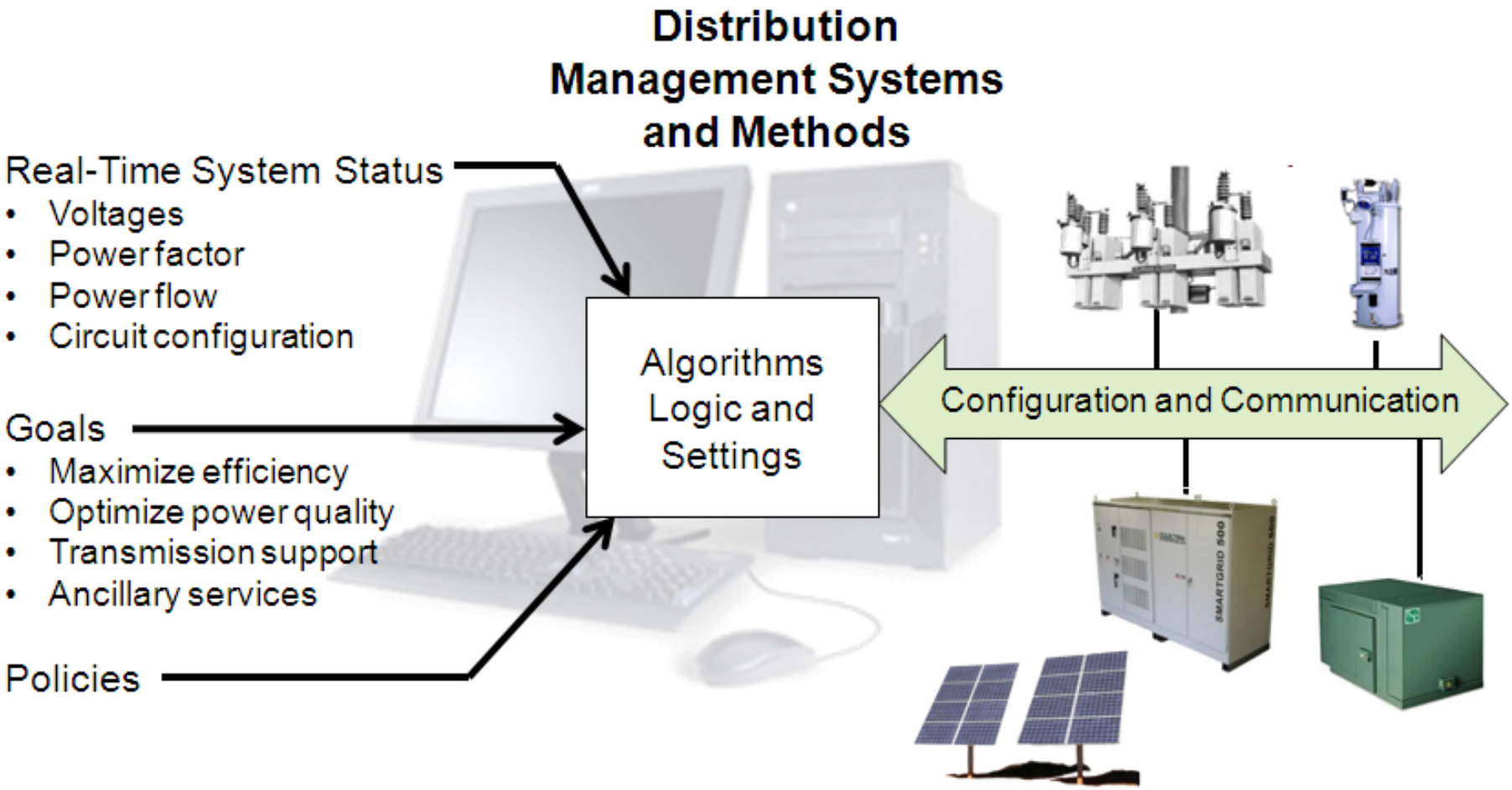
Smart Grid Vision for Advanced Inverters

Smart, Grid-Friendly Distributed Solar and Storage Systems as Beneficial Distribution System Assets



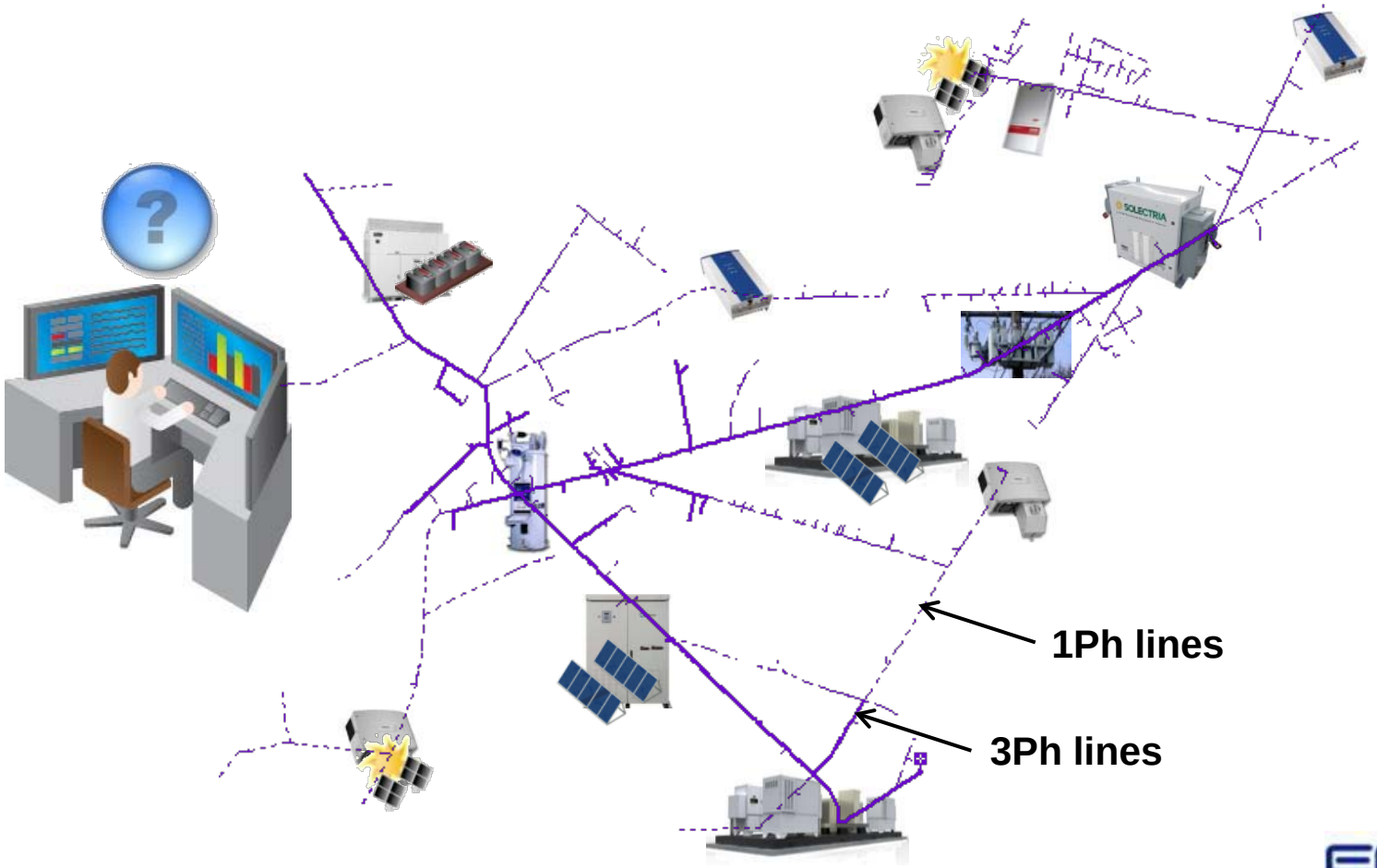
Inverters with smart-grid functionality can double DER capacity on the grid

How to Coordinate with Existing Controls?



Challenge to Integrate Smart Inverters

- *Many manufacturers… Many proprietary protocols*
- *Distribution Management Systems in infancy*



SMA
power-one
KACO new energy
SIEMENS
Fronius
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Better Technology. Better Results.
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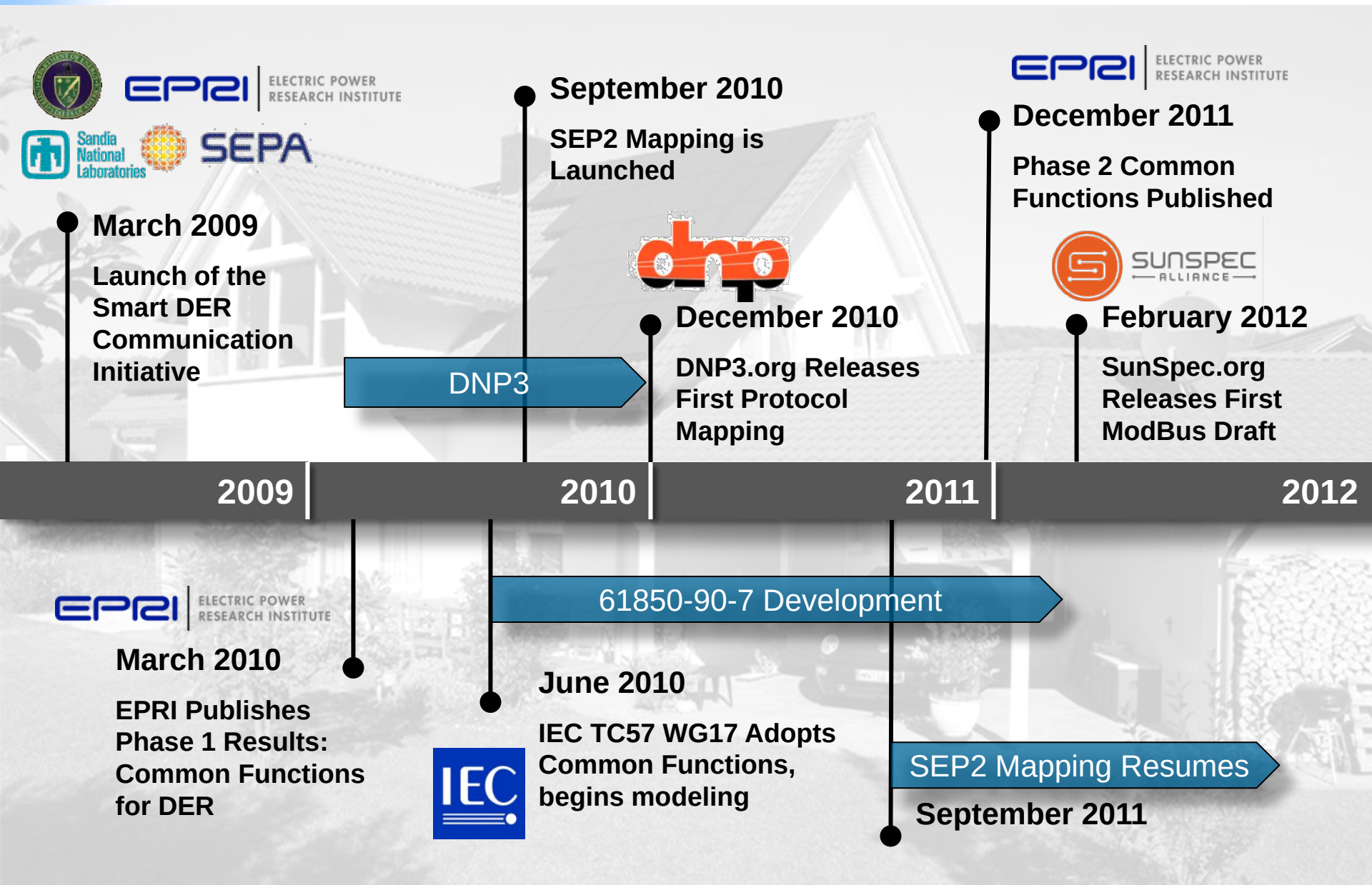
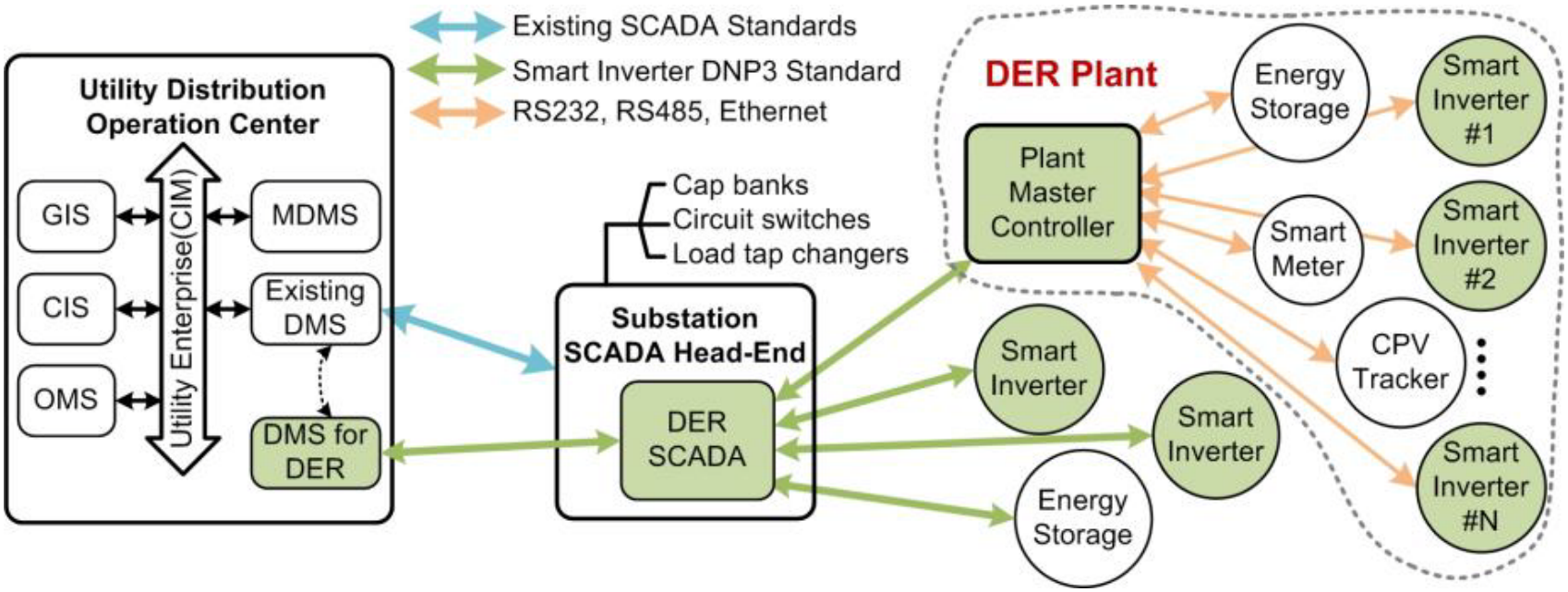
Addressing Communication Standard Challenge

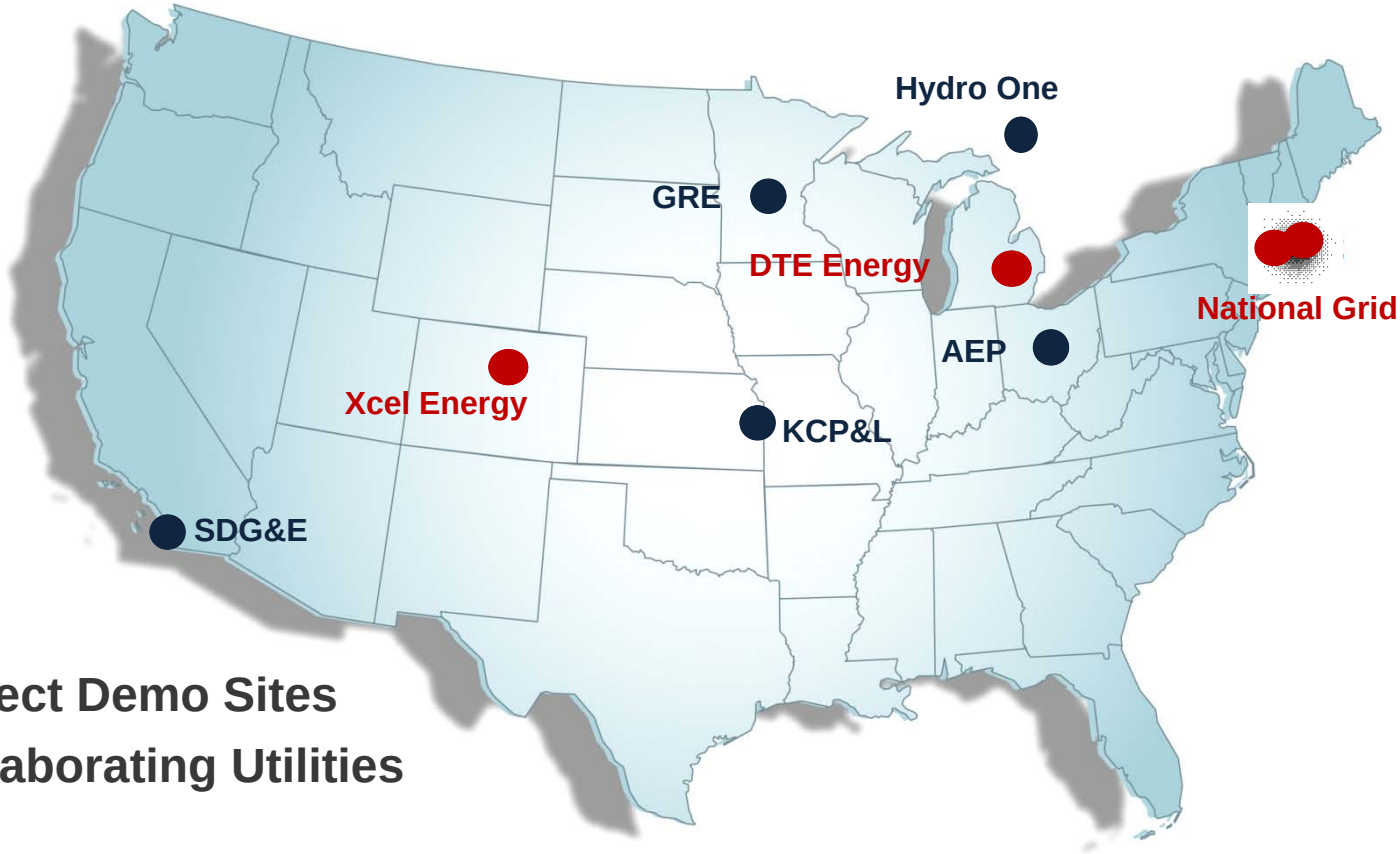


Smart-Grid Ready PV Inverter with Utility Communication



- **Three key components**
  - Developing smart-grid ready inverters
  - Demonstrating utility connectedness with smart-inverter
  - Demonstrate utility controlled unintentional islanding prevention

Utility Participants

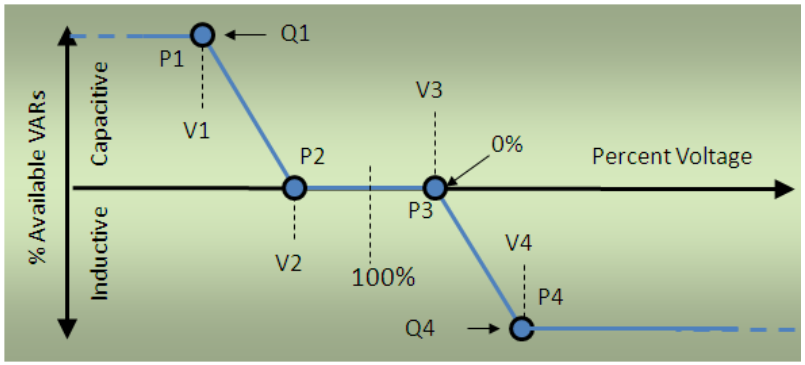


- DOE Project Demo Sites
- EPRI Collaborating Utilities

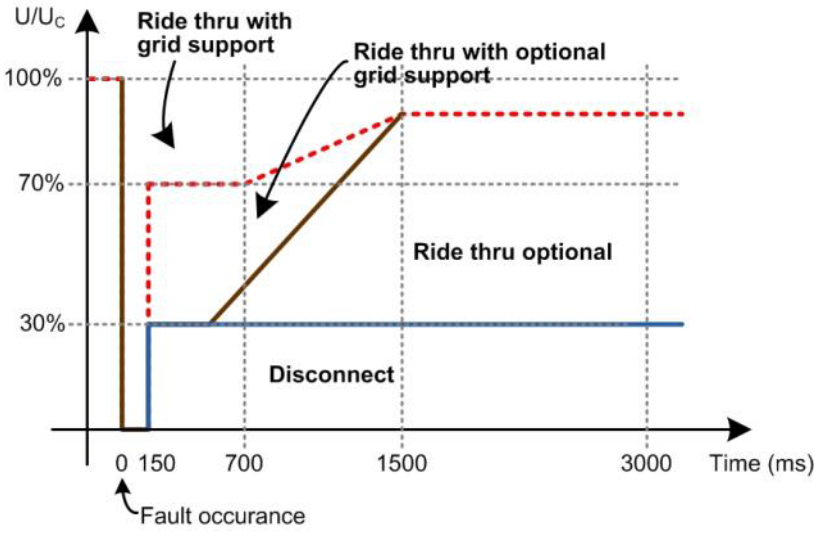
Inverter Grid Support Functionality

- Voltage regulation and reactive support
  - Volt-VAR control
  - Power factor setting
  - Dynamic reactive current support
- Active Power & ramp rate limiting
- Volt-watt control
- Frequency-watt control
- Dynamic response/LV ride-through

- Storage inverter specific functions
  - Direct charge/discharge management
  - Price-based charge/discharge function
  - Real power smoothing function
  - Load and generation following function
- Other Functions…



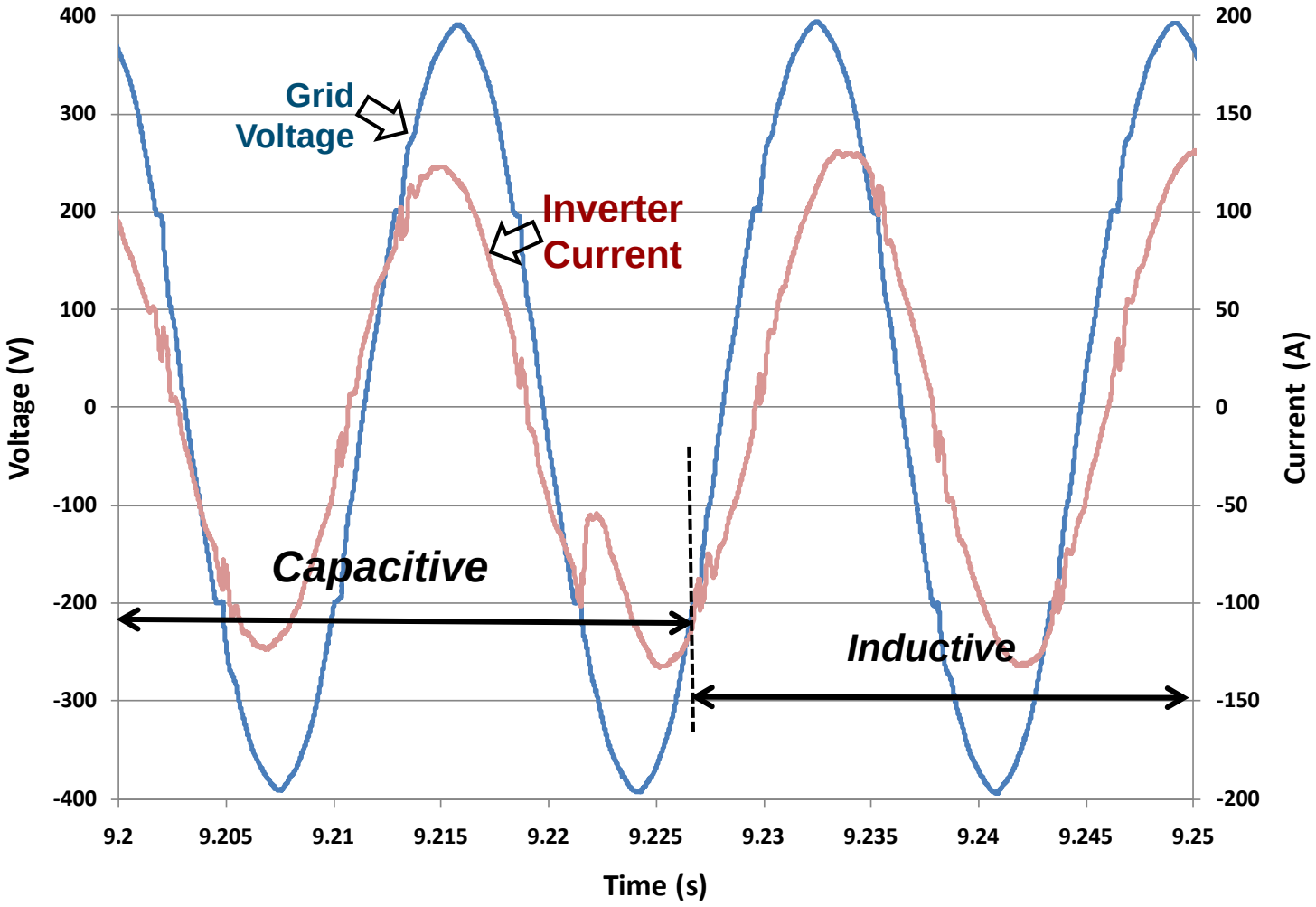
Example Volt-VAR Behavior (EPRI, 1023059)



LVRT in German MV Grid Code

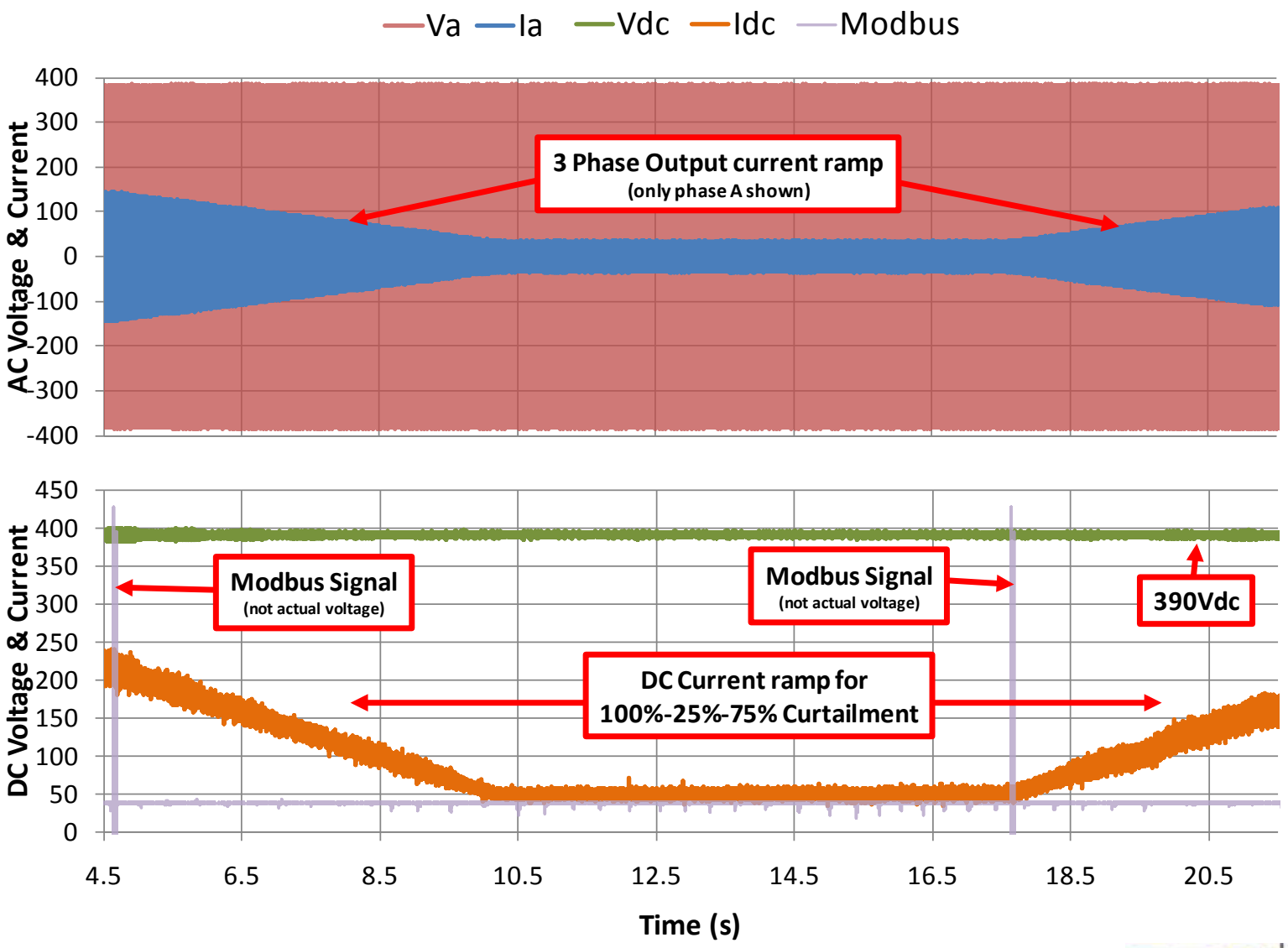
VAR Support

Finer steps and faster response compared to cap banks



Active Power Output Settings

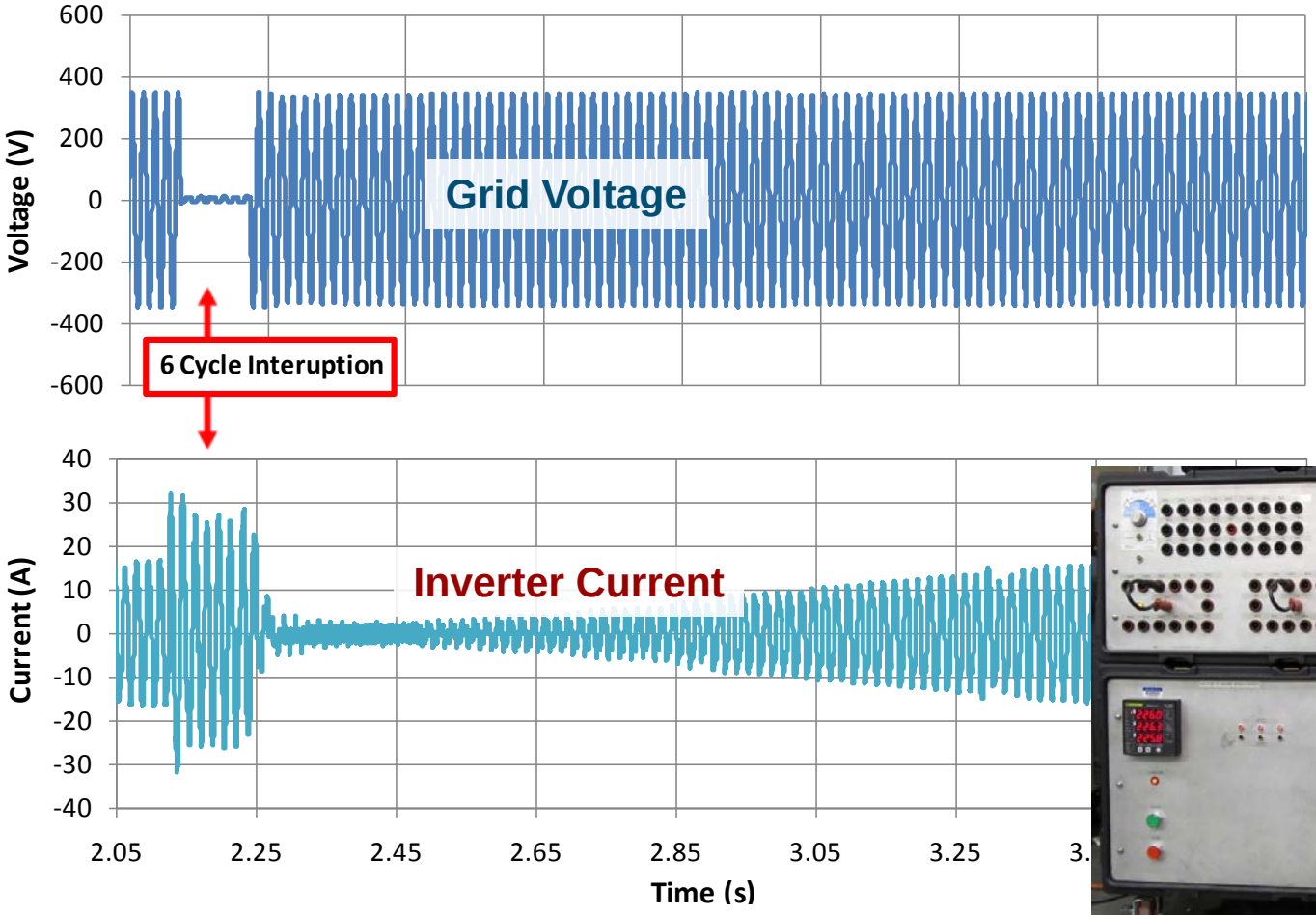
100% ➔ 25% ➔ 75%

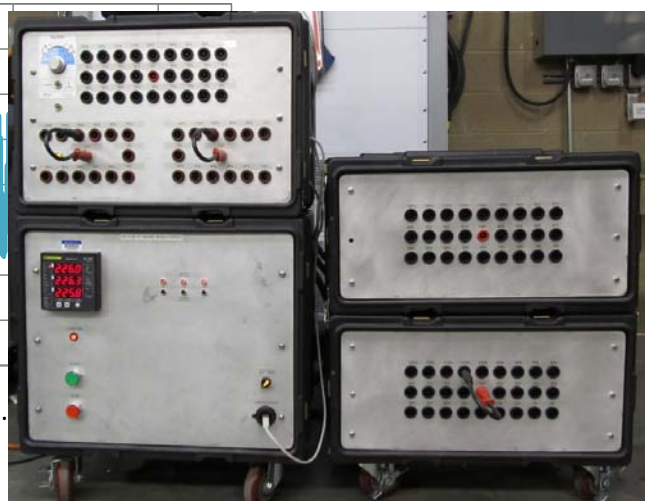


Voltage Sag/Interruption Ride-Through

Improving Grid Reliability

Inverter able to ride through momentary interruptions





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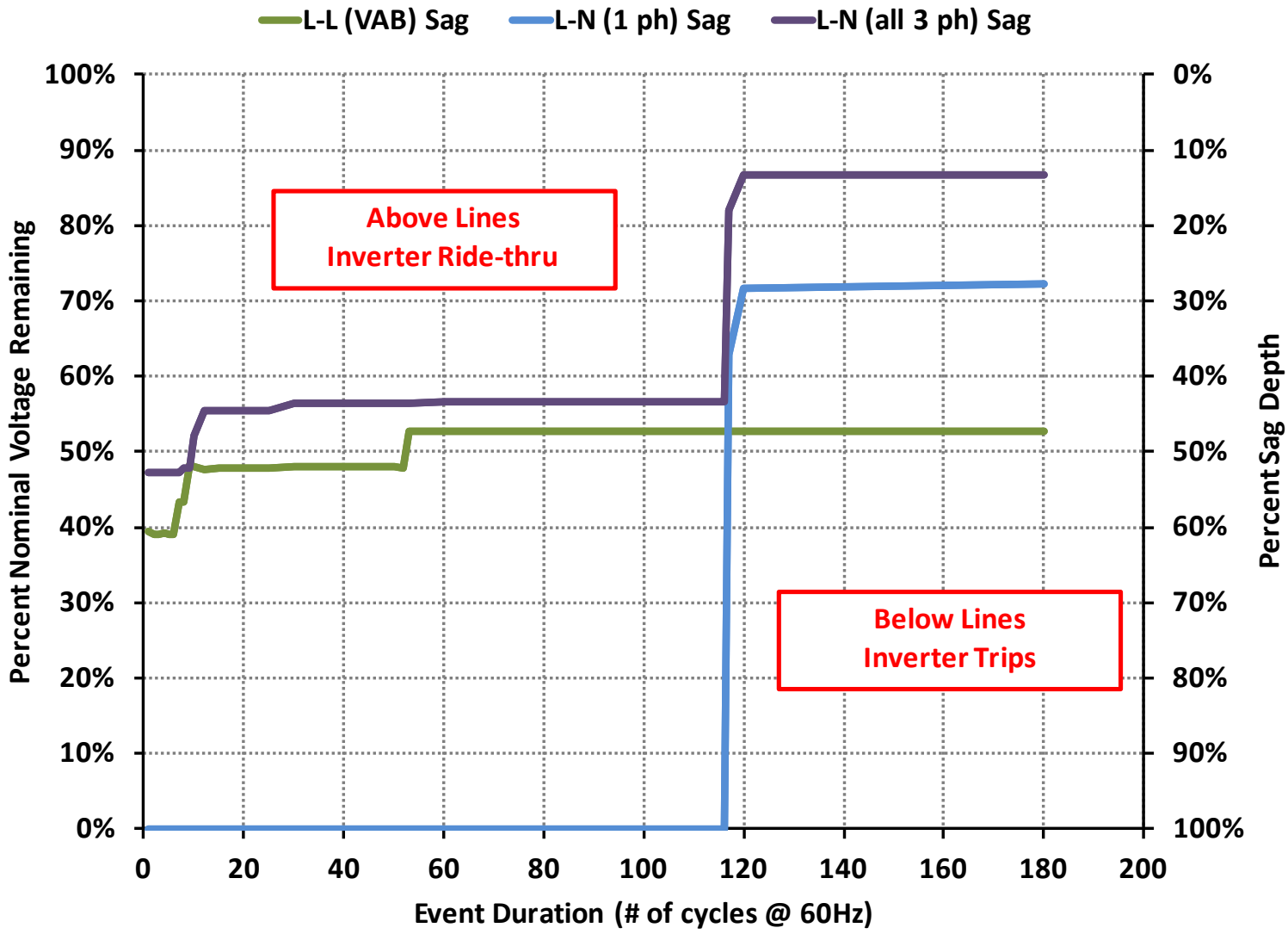
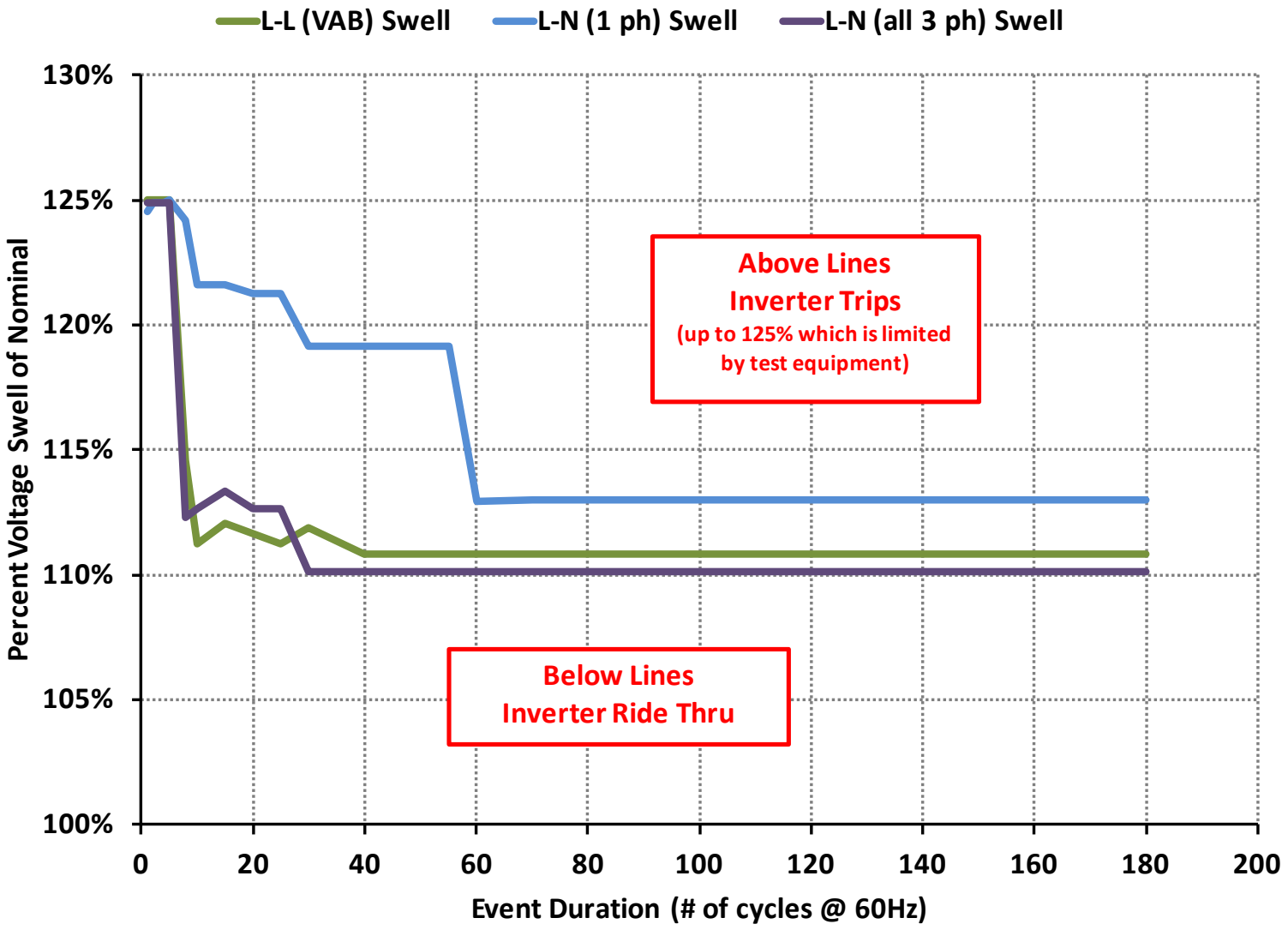
Voltage Sag/Interruption Ride-Through

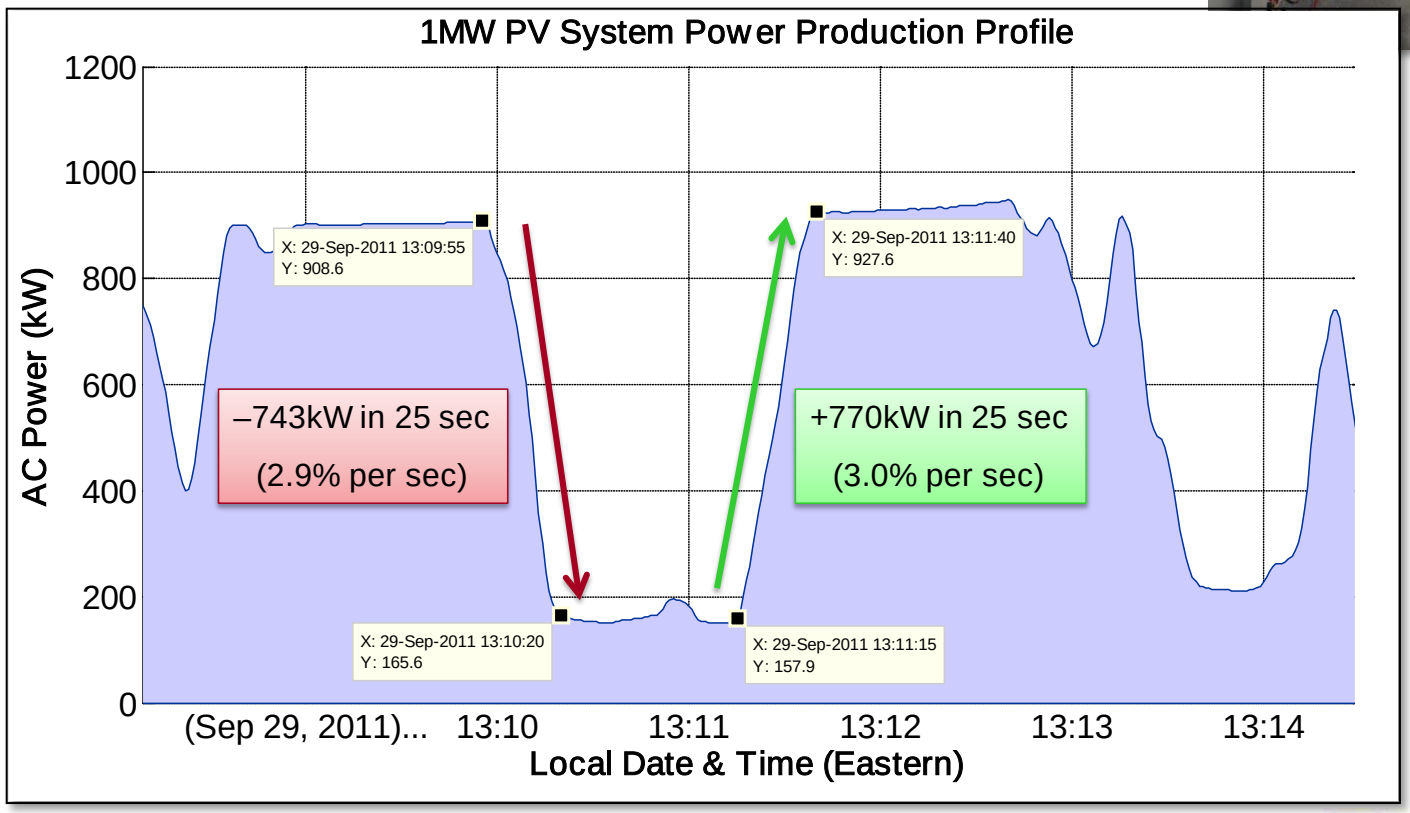


Voltage Swell Ride-Through



High-Resolution System Monitoring

- Collect high-resolution (1-sec) DER generation and environmental data
- Also capture power quality (PQ) events



PV output monitored to understand variability

High definition monitoring captures 1-sec data on any size PV system

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1MW PV System in Tennessee

Solar resource and AC output recorded at 1-sec resolution

1.0 MW_{dc}

- 3.5 acre
- Four 260kW inverters
- Data from Oct 2011

Single Module

8 Pyranometers

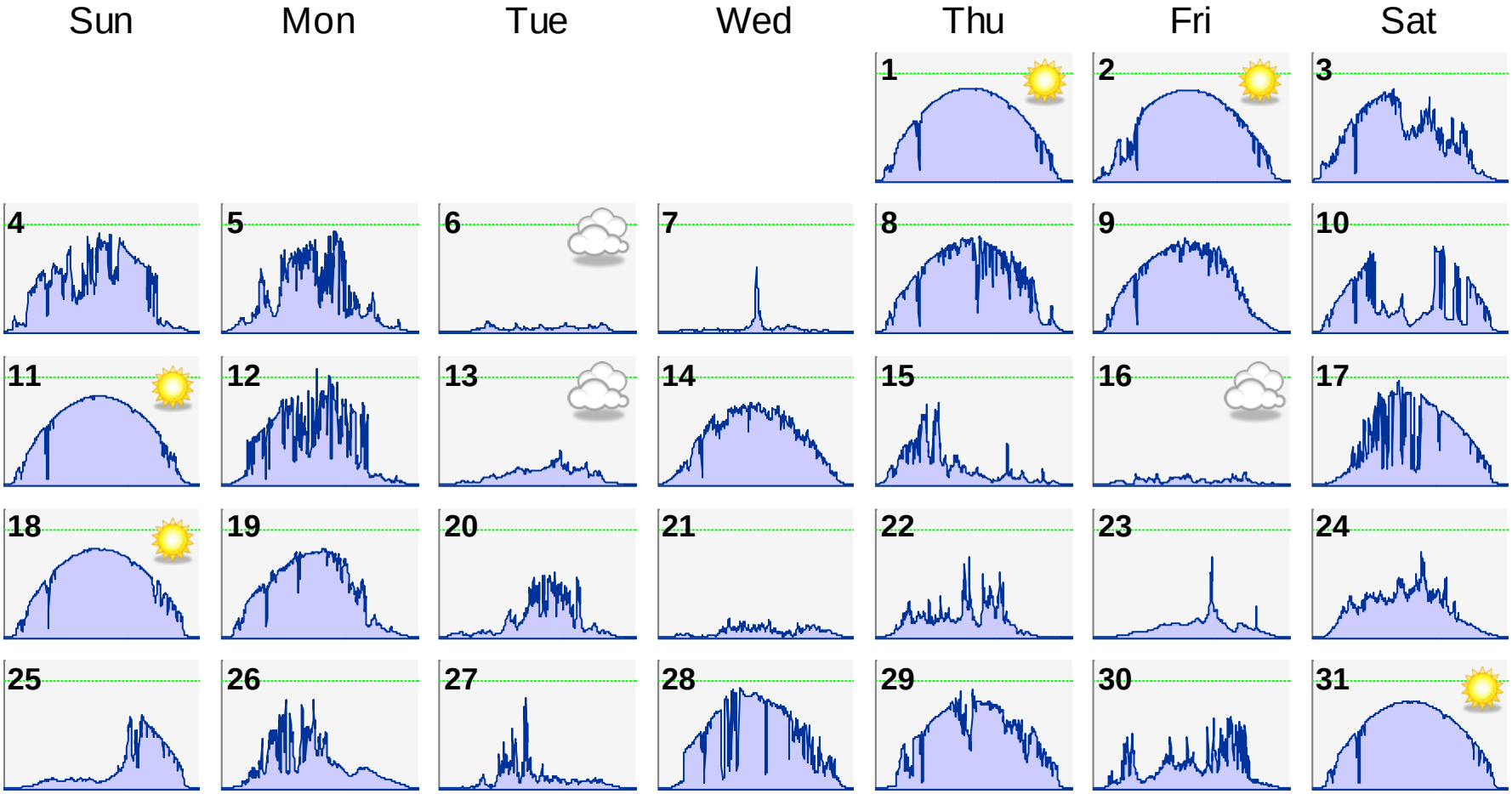
- 7 on PV system
- 1 on single-module
- Plane-of-array
- 25° fixed tilt, south

Pyranometer

Solar Resource Calendar – Single Pyranometer

December 2011 at 1MW PV site in Tennessee

December 2011: Tennessee Plane-of-Array Irradiance



Calendar profiles are 1-minute averages derived from 1-sec data

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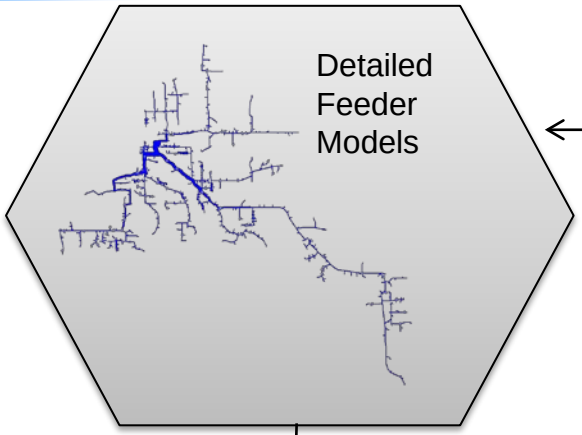
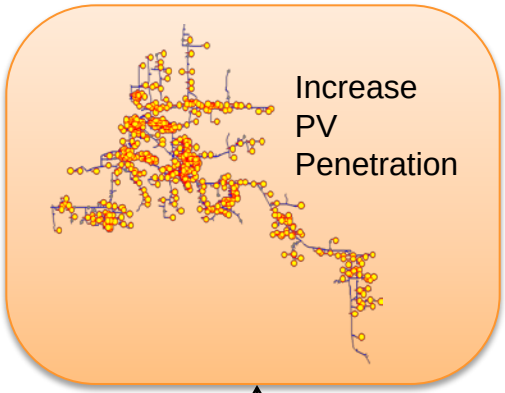
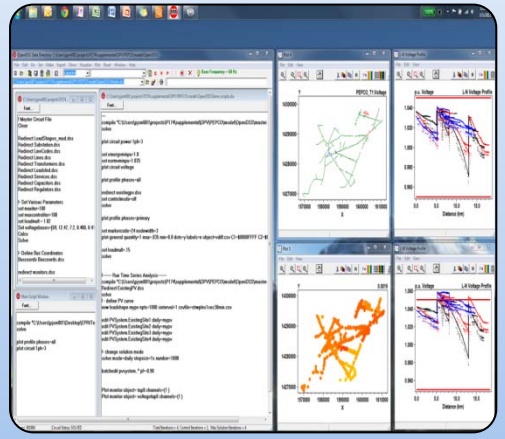
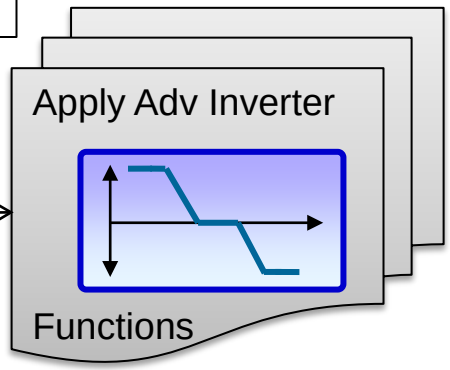
Feeder Modeling and Impact Analysis





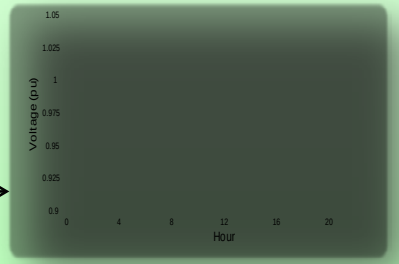
PV Feeder Impact Analysis
(OpenDSS)



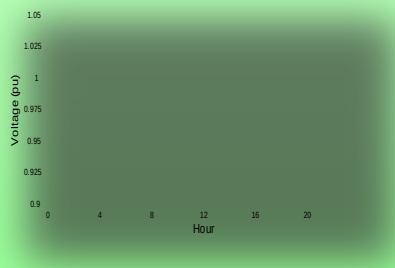


Feeder Impact Results

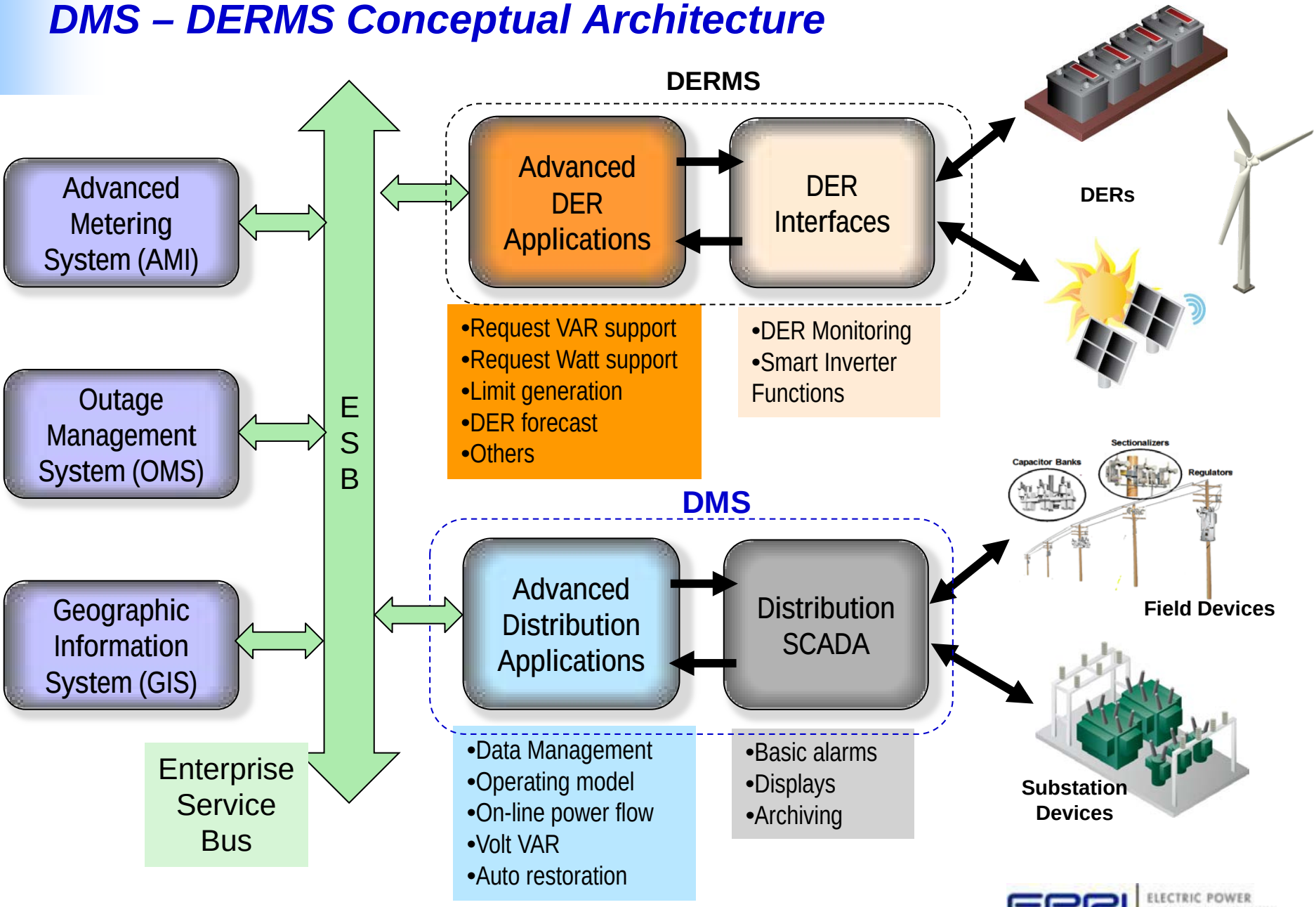
with adv functions



without adv functions



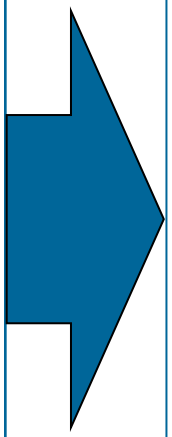
DMS – DERMS Conceptual Architecture



Enhanced DMS Functionality with DERMS

Conventional Functionality

- SCADA
- Volt-VAR Optimization
- FLISR
- Switching Orders
- Load Forecast
- Peak shaving
- Others



Enhanced Functionality

- Active distribution Control
- Enhanced VVO
- Enhanced FLISR
- Microgrid capability
- Firm renewables
- Market functions
- Others

Preventing Unintentional Islanding

Method	Description	Effectiveness	Cost	Compatibility with grid support functions
Passive	Monitor terminal voltage for trip conditions, but does not change inverter output to cause changes	Fair to poor, if high speed is needed	$	Good to excellent
Active	Actively change inverter output to cause change	Excellent in single inverter cases	$$	Poor to very poor
Communication based	Relies on communication for system awareness	Excellent (?)	$$$$	Excellent

Source: Michael Ropp, Northern Plains Power Technologies

Do We Need New Unintentional Islanding Prevention Method?

Most inverters use active anti-islanding which rely on the creation of an abnormal voltage to detect island formation

Conflicting

Grid support functions are all about correcting abnormalities in the voltage/frequency to maintain grid stability

Key communication based methods?

- Direct transfer trip (DTT)
- Power Line Carrier Permissive (PLCP)
- Synchrophasor-based methods

Cost

Effectiveness

Equipment reliability

Coverage area

EPRI Smart-Inverter Demonstration Project

Building Advanced Functionality into Inverters

Deploying in Diverse Field Environments

Collaborating – Sharing Plans and Results, Building Industry Knowledgebase

- ***Detailed insight into who is doing what***
- ***Understanding different functions and architectures***
- ***Understanding impacts through modeling and monitoring***
- ***Take away new tools and resources to use in other cases***
- ***Provide input to shape industry standards and future products***

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Together…Shaping the Future of Electricity

Aminul Huque

mhuque@epri.com

865-218-8051