NARUC Winter Policy Summit

Electricity Committee

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Moderator: Hon. Matt Schuerger

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Vice President of PV Systems, First Solar, Inc.

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Manager of Energy Systems Optimization and Control Group, Power Systems Engineering Center, NREL

Eric Lightner,
Director of Federal Smart Grid Task Force, DOE

Perspectives on Integrating Variable Resources Panel Session

Advanced Reliability Services from Utility-Scale Solar PV Plants

Mahesh Morjaria, Ph.D.
VP, PV Systems, First Solar

2017 NARUC Award Winner

Utility Industry Innovative Pilots or Demonstration Projects
CAISO/NREL/First Solar

http://www.caiso.com/Documents/TestsShowRenewablePlantsCanBalanceLow-CarbonGrid.pdf

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Demonstration of Essential Reliability Services by a 300-MW Solar PV Power Plant

Can variable energy resources provide essential reliability services to reliably operate the grid?

- NERC identified three essential reliability services to reliably integrate higher levels of renewable resources
    1. Frequency Control
    2. Voltage Control
    3. Ramping capability or Flexible Capacity

- Test results demonstrated utility-scale PV plant has the capability to provide these essential reliability services

- Advancement in smart controls technology allows these plants to provide services similar to conventional resources

- VERs (Variable Energy Resources) with the right operating characteristics are necessary to decarbonize the grid

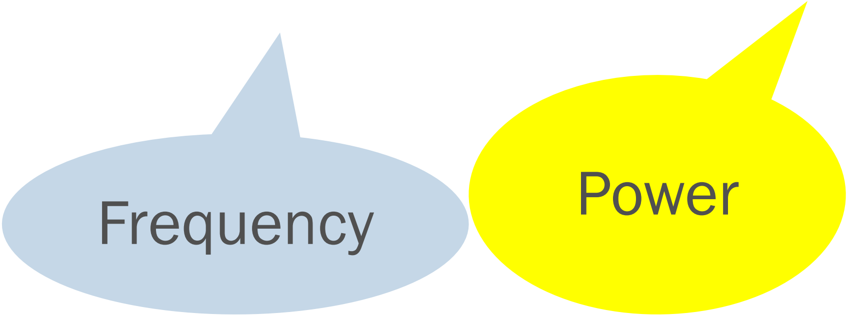
Summary of Conducted Tests

- *Regulation-up and regulation-down*, or AGC tests during sunrise, middle of the day, and sunset
- *Frequency response* tests with 3% and 5% droop settings for over-frequency and under- frequency conditions
- *Curtailment and APC* tests to verify plant performance to decrease or increase its output while maintaining specific ramp rates
- *Voltage and reactive power* control tests
- *Voltage control* at near zero active power levels (nighttime control)

Frequency Droop Tests

$$Droop = \frac{\Delta P / P_{rated}}{\Delta f / 60Hz}$$

- 3% and 5% under and over-frequency tests
- 20% headroom
- ±36 mHz dead band
- Used actual frequency event time series measured in the U.S. Western Interconnection



Changing Solar PPAs Could Turn Curtailed Power into Dispatchable Resources

"Too often, curtailment is automatically viewed negatively," said Chris Vlahoplus, Clean Tech and Sustainability Practice Leader at ScottMadden. "We wanted to explore a thoughtful approach to curtailment that might actually produce more flexible operations and better results for all parties involved."

"You're not curtailing; you're turning the power into ancillary services that create a new value stream for the grid, and customers are getting the benefit. "
John Sterling, SEPA's Senior Director

Dispatchable PV Plant

- Solar can provide NERC-identified essential services to reliably integrate higher levels of renewable resources, including:
  - Frequency Control
  - Voltage Control
  - Ramping capability or flexible capacity
- Automated Generation Control (AGC) regulation accuracy of 24-30 %points better than fast gas turbines
- Reduces need for services from conventional generation
  - Goes beyond simple PV energy value
  - Enables additional solar
  - Reduces need for expensive storage

CAISO: "Grid Friendly Utility-Scale PV Plants are Essential for Large-Scale PV Integration"

http://www.caiso.com/Documents/TestsShowRenewablePlantsCanBalanceLow-CarbonGrid.pdf

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Grid Integration of Renewable Energy: Challenges and Opportunities

Murali Baggu
Manager – Energy Systems Optimization and Control

Power System Engineering Center
National Renewable Energy Laboratory

Perspectives on Integrating Variable Resources Panel Session

Mitigation Strategies Employed

Type of Mitigation Strategy	
Upgraded line sections	Grounding transformers
Modify protection	Reclosers
Voltage Regulation devices	Static VAR Compensator
Direct Transfer Trip	Capacitor control modifications
Advanced inverters	Volt/VAR Controls
Communication/Control Technology	Power factor controls

Slide Courtesy: Interconnection Processes and Procedures in 21 U.S. Utilities **Michael Coddington Principal Engineer,** *National Renewable Energy Laboratory*

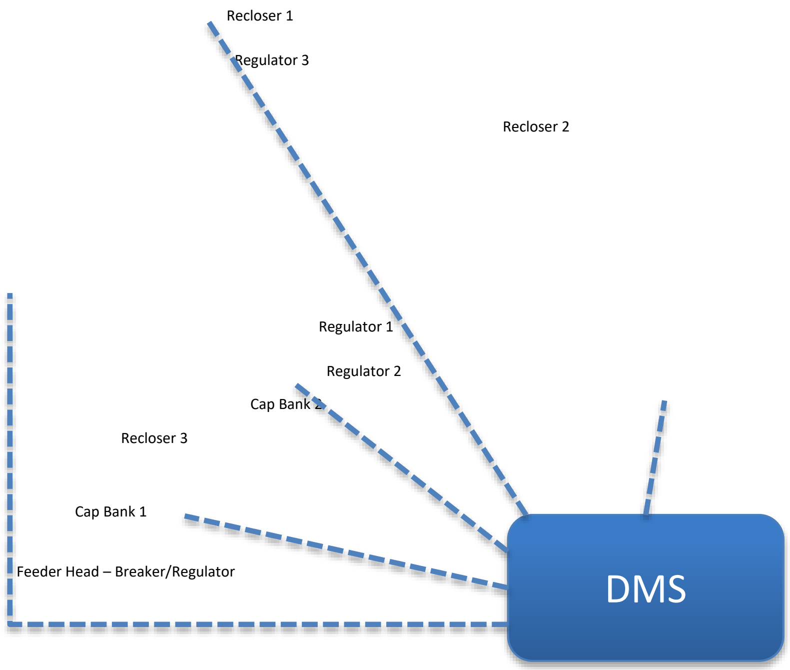
Case Study 1: Voltage Regulation Using Smart PV Inverters

- Serving ~4.15 square miles, Peak load = 9.89MW
- One controllable 1200 kVAr capacitor: switch on at 6 am, switch off at 10 pm
- ~1 MW existing PV power with standard inverters (~10% penetration)
- ~700 kW planned PV with smart inverters (~7% penetration)
- ~500 kW planned PV with standard inverters (~5% penetration)
- Planned PV Systems are distributed at 16 service transformer locations.

F. Ding, A. Pratt, T. Bialek, F. Bell, M. McCarty, K. Atef, A. Nagarajan and P. Gotseff, "Voltage support study of smart PV inverters on a high photovoltaic penetration utility distribution feeder," in IEEE 43rd Photovoltaic Specialists Conference (PVSC), Portland, OR, June 2016.

Conservation of Voltage Reduction

- Normally performed by flattening the system voltage using capacitor banks and/or voltage regulators and lowering the voltage by controlling a substation Load Tap Changer
- Also performed by using a central volt/VAR optimization performed by a distribution management system (DMS)
- Depends upon the type of the feeder

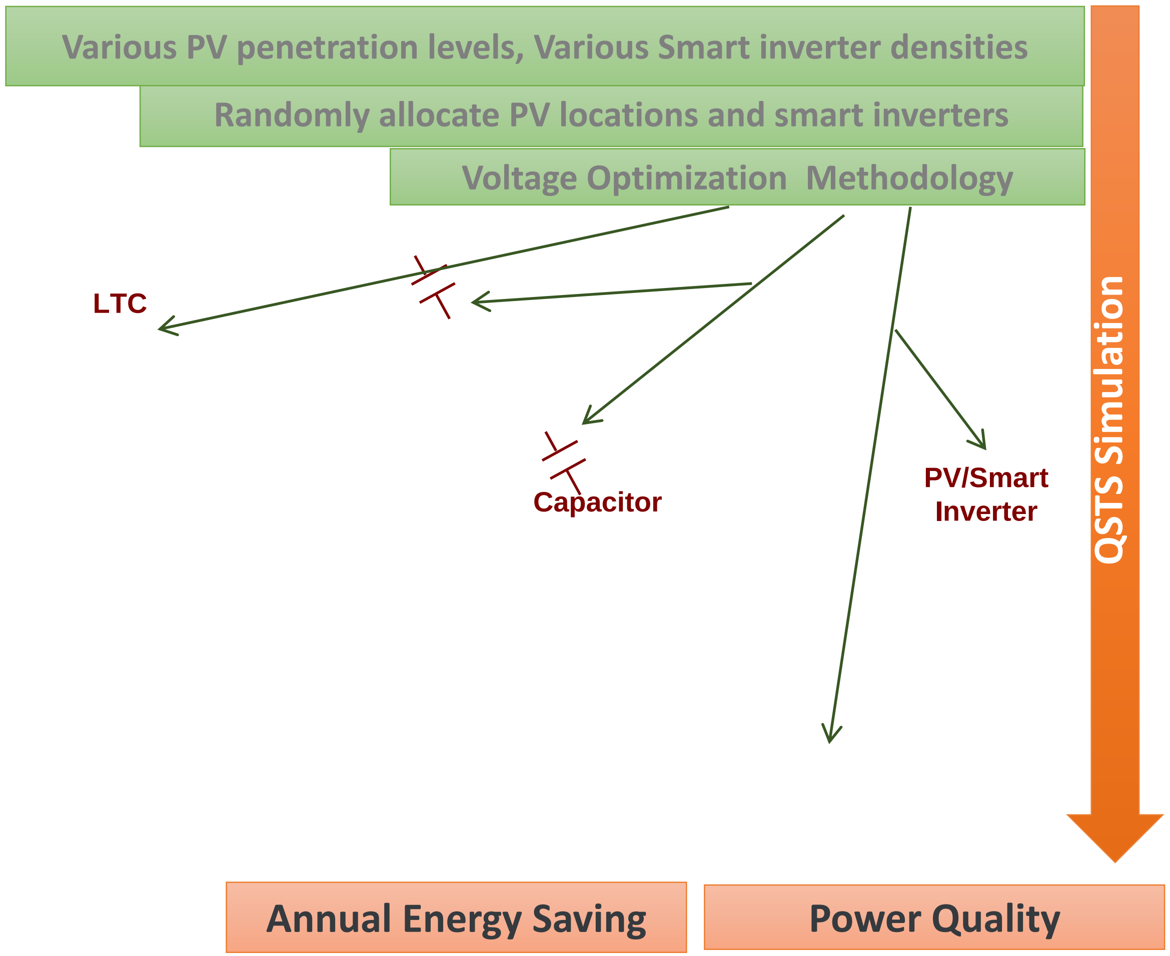


Conservation of Voltage Reduction (CVR): *A voltage reduction scheme that flattens and lowers the distribution system voltage profile to reduce overall energy consumption.*

Case Study 2: Voltage Support Using Smart PV Inverters

Objective: Evaluate the effects of distributed PV with smart inverters on the conservation of voltage reduction (CVR) energy savings and power quality in distribution systems.

F. Ding *et al.*, "Application of Autonomous Smart Inverter Volt-VAR Function for Voltage Reduction Energy Savings and Power Quality in Electric Distribution Systems," *IEEE* Innovative Smart Grid Technologies , Washington DC, 2017.



Case Study 3: Feeder Voltage using Advanced Inverters and a Distribution Management System

TECHNOLOGY ADDRESSED

Understand impacts of smart inverters on distribution systems and advanced distribution management systems

R&D STRATEGY

NREL and GE Grid Solutions implemented a comprehensive modeling, analysis, visualization and hardware study using a representation of Duke Energy’s utility feeder.

IMPACT

Enable greater adoption of smart inverters at utilities by addressing the challenges of integrating them with GIS, DMS, OMS and SCADA systems.

Distributed Energy Resource Management Systems

- DERMS provide situational awareness, control/dispatch and monitoring of DERs in the distribution system:
  - PV with and without smart inverters
  - Energy storage
  - Electric vehicles

Enterprise Systems Integration and Interoperability

- Seamless Integration among multiple systems
- Sharing common platform
- IT- OT convergence
- Cybersecurity
- Integration of different data systems to enhance decision making

Short term planning and operations

Convergence of systems operations and short term planning

- Generate possible control scenarios for optimal system operation
- Spatial and temporal visualization of multiple scenarios and possible mitigation measures
- Cost and Benefit Analysis

Behavioral analytics and data driven approaches

Look ahead State Estimation:

- Using real-time measurements such as data from AMI, Sensors, PMUs and DMUs
- state estimation using machine learning approach to solve for the highest probable states for the entire system.
- Locational benefit is desirable feature for nodal pricing and can therefore be more reflective of system conditions such as congestion

Energy Storage System Potential

- Understand the value ESS can generate when they are highly utilized by ***stacking*** multiple grid services.
- Standardizing a framework to perform multi service dispatch of ESS including:
  - Co-simulation of an optimization suite along with a **distribution power flow simulator**
  - Identification of **use-cases that can provide positive net value** to the electricity system under prevailing energy-storage cost structures.

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Conclusion

- Battery degradation plays a very important role in assigning value to energy storage
- Capacity sharing mechanisms increases the ESS utilization significantly
- Perform system studies to understand the other stacking combinations

- Simplified approach: The average value calculated was ~$40/day, which compares relatively well with the $80-$30/day values calculated by the MIP markets model

CEC project: SDG&E's Borrego Springs Microgrid

Borrego Springs, served by one transmission line that extends 60 miles

- Expanding an existing small microgrid demonstration
- A 26 MW PV plant that,
- substation and community-scale batteries
- and ultra-capacitors,

Enables the entire community to operate solely on renewable energy

Eric Lightner
Director, Federal Smart Grid Task Force
Advanced Grid Research, Office of Electricity
US Department of Energy

U.S. DEPARTMENT OF ENERGY

VOICES OF EXPERIENCE | INTEGRATING INTERMITTENT RESOURCES

- Utilities large and small – from across the country – are interested in the topic
- Participants wanted to be proactive in discussing challenges and successes

Message from utilities on the leading edge:

START PREPARING NOW

- Expect Exponential Growth
- Capture Load Profiles
- Develop Your Tools

OPERATIONAL CONSIDERATIONS
TURNING GRID OPERATIONS UPSIDE DOWN

Before voltages decreased along the circuit, need for load curtailment on peak days. Now voltages rising along the circuit; capacity curtailment on days with high solar output and low load

- Location, size, and ownership matter
- Operators need visibility and control
- Operating and maintenance costs can be impacted
- System upgrades might be needed even with non-wire solutions
- Generation mix will determine how the grid is operated and the solutions that can be employed to address intermittency

ADVANCED INVERTERS

AN EMERGING TECHNOLOGY

- Advanced (or smart) inverters may help utilities better integrate customer-owned distributed generation
- Advanced functionality is relatively new
- Utilities are using field tests and demonstration projects to better understand how the inverters can be used to support their operational objectives

HOSTING CAPACITY STUDIES

WHY DO YOU NEED THEM?

- **Interconnections:** Streamline the process and approve applications more quickly
- **Planning:** Provide a stress test for the system
- **Policy:** Understand policy implications from a system perspective
- **R&D:** Help identify operation margins & areas that need further study
- **Communications:** Provide customers and decision makers with system constraint information

Planning and Forecasting
No longer a straightforward process

Growing complexity and uncertainty

- *Uncertainty*
  - Shifting peaks
  - Impact of hourly weather changes
  - Solar growth rate
  - Unpredictable load profiles
- *Complexity*
  - Evaluating Wire and Non-wire solutions
  - More operational possibilities with smart grid technologies
  - Transition to 8760 quasi-dynamic load flow analysis
  - Generation flowing to and from the utility

NEW VOICES EFFORT

How utilities are leveraging AMI and its Data

- Two areas:
  - Operational improvements
  - New customer programs
- Document release early summer

QUESTIONS TO EXPLORE

- How is AMI helping to improve operations?
- How is AMI enhancing the customer experience?
- What new customer programs has it enabled?
- What value is being extracted from the data?
- What offers the most potential from the technology or its data?
- What are the biggest challenges to achieving the value?

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