Photovoltaic And Renewable Energy Systems Research

Clifford W. Hansen
SW Regional Energy Workshop
March 14, 2018
Premier PV module laboratory

Purpose
- Focus on Emerging Technologies
- Minimum 1-year installations
- Data used to validate energy yield predictions
- Evaluate system reliability and degradation rates

Configuration and Capacity
- 750kW grid tie capacity
- 225 kW currently installed
- 100-125kW near term expansion (just need modules and inverters)
- 225-275kW mid term expansion (need site prep, racking, electrical runs)

Instrumentation
- DC Voltage and Current (string and combiner)
- AC Voltage, Current and Power Factor
- Module Temperature
- Full weather station
**Indoor Module and Cell Characterization**

**Solar Simulator**
- Spire 4600SLP
- Characterize IV behavior of modules as a function of irradiance
- 200-1100 W/m²
- Room temperature operation only

**Module Inspection**
- Reltron PV Electroluminescence Inspection System
- Custom enclosure and module mounting

**Light-soaking/Pre-conditioning Chamber**
- Temperature controlled light-soaking chamber, integrated IV sweep capability

**Cell characterization workbench**
Sandia manages the US DOE Regional Test Center (RTC) Program

1. Demonstrate Performance of Product: “It Works”

2. Demonstrate long-term Field Performance: “It lasts”

3. Demonstrate long-term Field Performance: “It lasts here”
## Industry Benefits from RTC Program

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Images</th>
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<tbody>
<tr>
<td>Multi-climate field studies</td>
<td><img src="image1.png" alt="Image" /></td>
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<tr>
<td>High-fidelity performance and meteorological data</td>
<td><img src="image2.png" alt="Image" /></td>
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<td>Performance analysis</td>
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<td>Bankability/technological validation</td>
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<td>Product development: access to lab capabilities and expertise</td>
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PV Lifetime Project

- Develop and standardize methods for measuring PV module and system degradation.
  - The path of degradation matters to LCOE.
- Apply methods to selected commercial PV modules
- Three sites: New Mexico, Colorado, and Florida
- 700 modules total (~50 in each manufacturer sample)
  - Targeting top-selling module manufacturers (in US market) and a range of current cell technologies (focus on Si)
  - Statistical characterization of variation in degradation within a module population
Bifacial Research Project

Collaborative project between Sandia, NREL and University of Iowa
(https://pvpmc.sandia.gov/pv-research/bifacial-pv-project/)

Task 1: Measure Outdoor Bifacial Performance

- Module, string and system scale
  - Adjustable rack with 4 modules
  - Fixed tilt racking with varying tilt and azimuth
  - Single axis and two-axis trackers
  - Arid sunny (NM and NV) and cold snowy climates (VT)
  - Irradiance measurements (rear-facing, spatial)

- Quantify
  - Performance of mono- and bifacial modules in similar deployments
  - Bifacial gain – see next slide
  - Spatial variability in backside irradiance
  - Effects of backside obstructions and shading
Bifacial Research Project (cont.)

Task 2: Develop Performance Models

- Irradiance modeling
  - Ray tracing methods – Sensitivity studies
  - View (Configuration) Factor methods: 2D for conventional arrays, 3D for cell-by-cell irradiance
- Module performance models

Task 3: Support Rating Standards

- Support new bifacial rating standard (IEC 60904-1-2 - Draft)

Publications at
https://pvpmc.sandia.gov/pv-research/bifacial-pv-project/
PV Performance Modeling Collaborative

- pvpmc.org
  - Online reference for PV system modeling
- PVLib for Matlab and pvlib-python
  - Open source implementation of PV modeling tools
- Registration Open!! 2018 10th PV Performance Modeling and Monitoring Workshop in Albuquerque, New Mexico USA (1-3 May 2018)
  - Performance modeling, EPRI/SNL Systems Symposium, PVLib user group
Why do we need QSTS?

QSTS simulations are needed today to understand:

- Rapid fluctuations due to high variable PV
- Impact to voltage regulators and switched capacitors
- Temporary extreme conditions before controls react
- Research new distribution control strategies

Distribution System Analysis Methods and Tools

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<thead>
<tr>
<th></th>
<th>Extreme Voltages</th>
<th>Thermal Loading</th>
<th>Regulators Tap Changes</th>
<th>Capacitor Switching</th>
<th>Time outside ANSI</th>
<th>Losses</th>
<th>Computation Time</th>
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<tbody>
<tr>
<td>Snapshot</td>
<td>Good</td>
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ProDROMOS (open-source components for Virtual Power Plants)

- Programmable Distribution Resource Open Management Optimization System (ProDROMOS)
Cybersecurity for DER

SunSpec/Sandia DER Cybersecurity Workgroup

Communication and Protocol Security
- Define requirements and draft language for data-in-transit security rules.
- Lead: TBD
- Authentication
- Encryption requirements
- Acceptable transport protocols

Secure Network Architecture
- Create DER control network topology requirements and interface rules.
- Lead: Candace Suh-Lee (EPRI)
- Segmentation
- Perimeter control
- Physical security

Access Controls
- Classify data types, associated ownership, and permissions. Define set of protection mechanisms.
- Lead: TBD
- Access control lists
- Password control
- Data privacy

DER/Server Data and Communication Security
- Define standardized procedure for DER and server vulnerabilities assessments.
- Leads: Cedric Carter (Sandia) and Danish Saleem (NREL)
- Known equipment vulnerabilities
- Establish certification and auditing procedures (e.g., UL 2900, IEC 62351 Parts 3 and 4)
- Maintaining compliance, requirements for patching
Stochastic Unit Commitment Algorithms

- Reduce operating costs due to variable generation and imperfect forecasts
  - Leverage stochastic optimization engines
  - Methods for representing forecast uncertainty

Day-ahead hourly wind generation forecasts (Bonneville Power Authority)
Deterministic UC vs. Stochastic UC

Deterministic: 2017-03-18
CP: 0 – 0.01 – 0.5 – 0.99 – 1

Stochastic: 2017-03-18
CP: 0 – 0.01 – 0.5 – 0.99 – 1

Large reduction in load-not-met and elimination of reserve shortfall in stochastic case