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Distributed PV Monitoring

Highlights for PV Grid Integration Workshop

Tucson, Arizona

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Overview of EPRI's DPQI and DPQII Power Quality Monitoring Studies

	DPQ Phase I	DPQ Phase II
Number of Sites	277*	480**
System Level Monitored	3	8
Monitor●Days	146,661	541,399

* 300 sites were selected during site selection

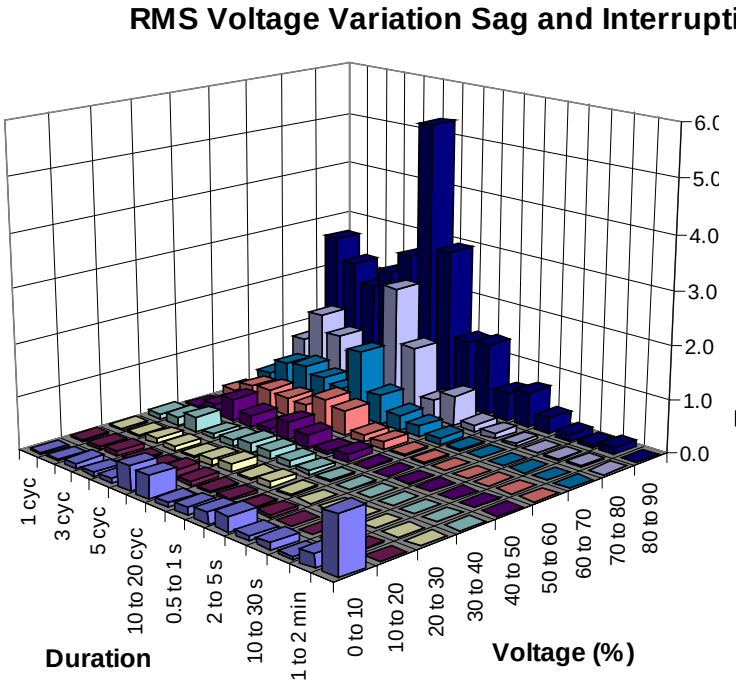
** 493 sites were selected during site selection

EPRI's DPQI and DPQII Power Quality Monitoring Studies

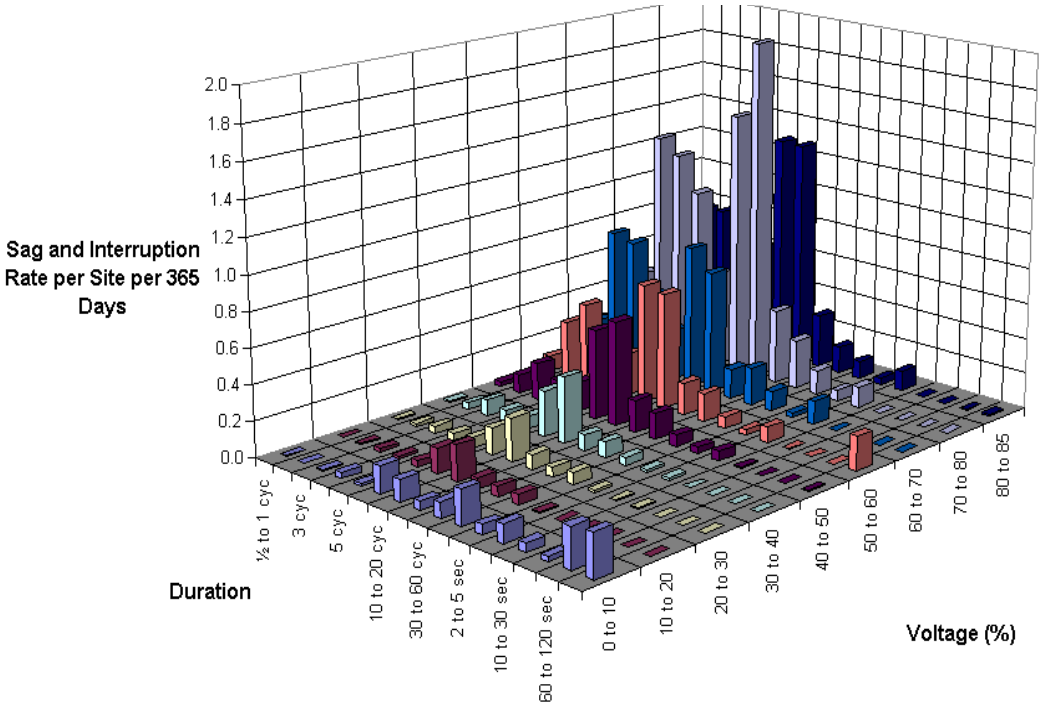
- Since DPQI Phase I completion in 1995, many utilities have implemented system-wide PQ monitoring programs on distribution and transmission.
- Wealth of data provided unique opportunity for Round II, DPQ. (2001-2002)
- DPQI PQ along the feeder (sub, middle, end), DPQII (various locations on feeder)

Sag and Interruption Annual Rates (Magnitude/Duration Histogram)

DPQ Phase I, 0 – 90% Voltage



DPQ Phase II, 0 – 85% Voltage

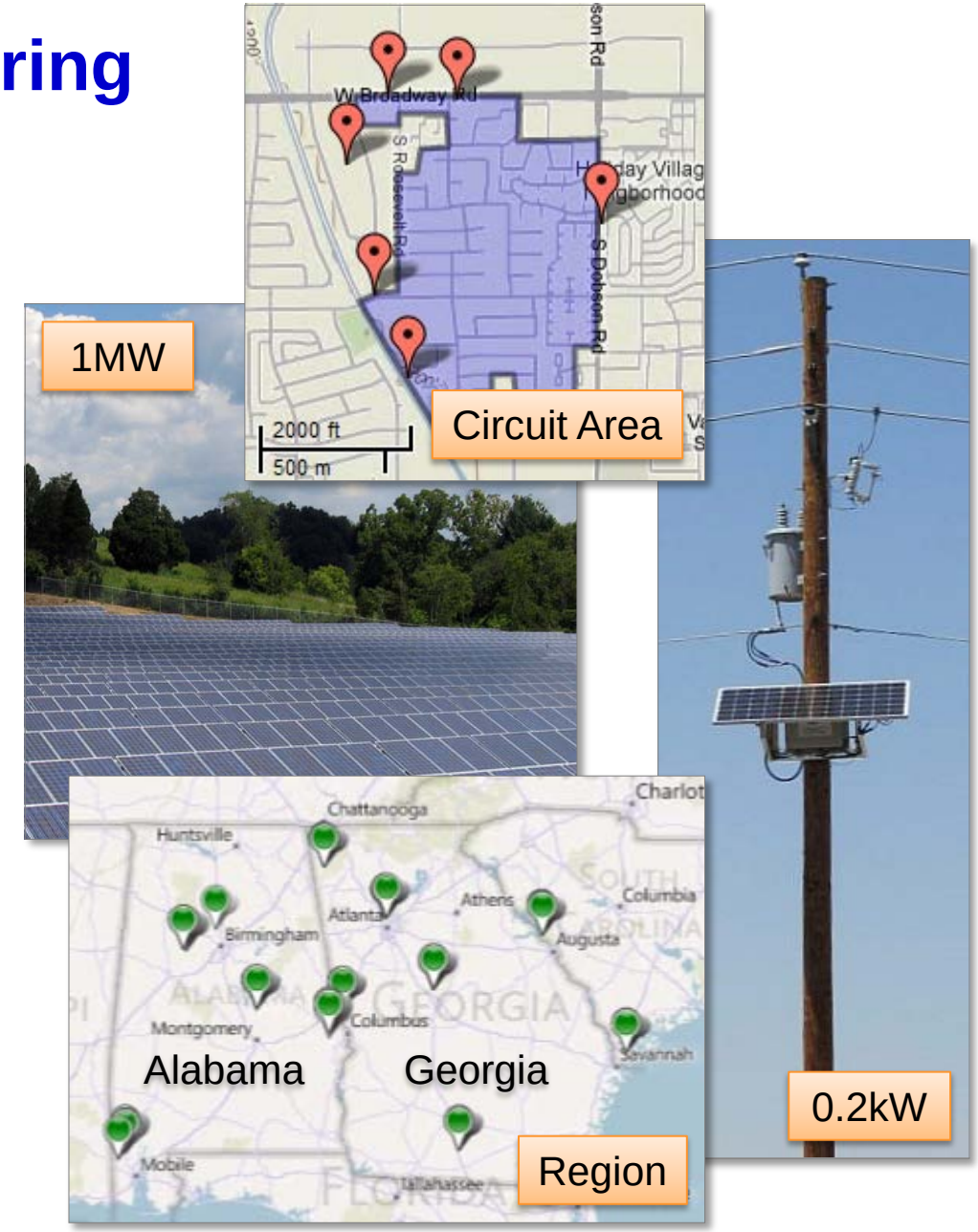


Distributed PV Monitoring

An EPRI Research Project

Field monitoring to characterize PV system performance & variability

- **Utility interactive PV systems**
  - ✓ Single modules on poles
  - ✓ 1MW plants
  - ✓ 200+ sites committed nationwide
- **Field measurements for 1+ years**
  - ✓ AC power meter
  - ✓ Plane-of-array pyranometer
  - ✓ Module surface temperature
  - ✓ …More sensors on select sites
- **Data acquisition**
  - ✓ 1-second resolution
  - ✓ Time synchronized
  - ✓ Automated uploads to EPRI
  - ✓ Structured data storage at EPRI



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PV systems small and large are monitored

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

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Monitoring for Central Inverter PV Systems

Instrumentation for solar resource, selected dc points, and ac output

Data acquisition: up to 1-second recording, automatic data transfers, internet time synchronization, remote login

Solar Resource

- **Irradiance**: plane-of-array, global horizontal
- **Weather**: temperature, humidity, wind, rain

PV Array

- **Module**: dc voltage, current, back temperature
- **Combiner box**: dc voltage, string currents

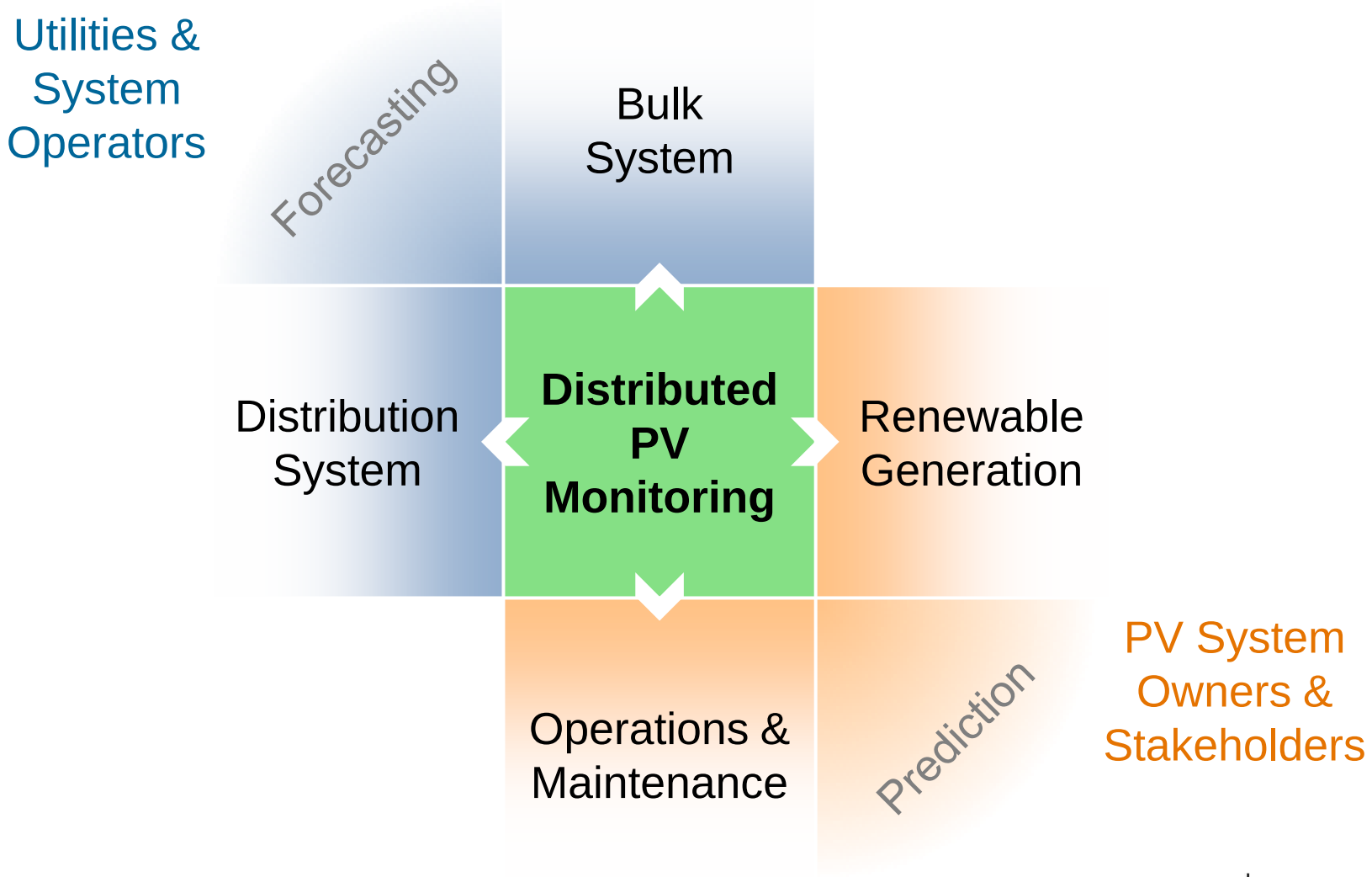
Inverter

- **Input**: dc voltage, current
- **Output**: ac power, energy totals (real & reactive), voltage, current

Instrumentation designed, assembled, configured, and tested by EPRI for field installation

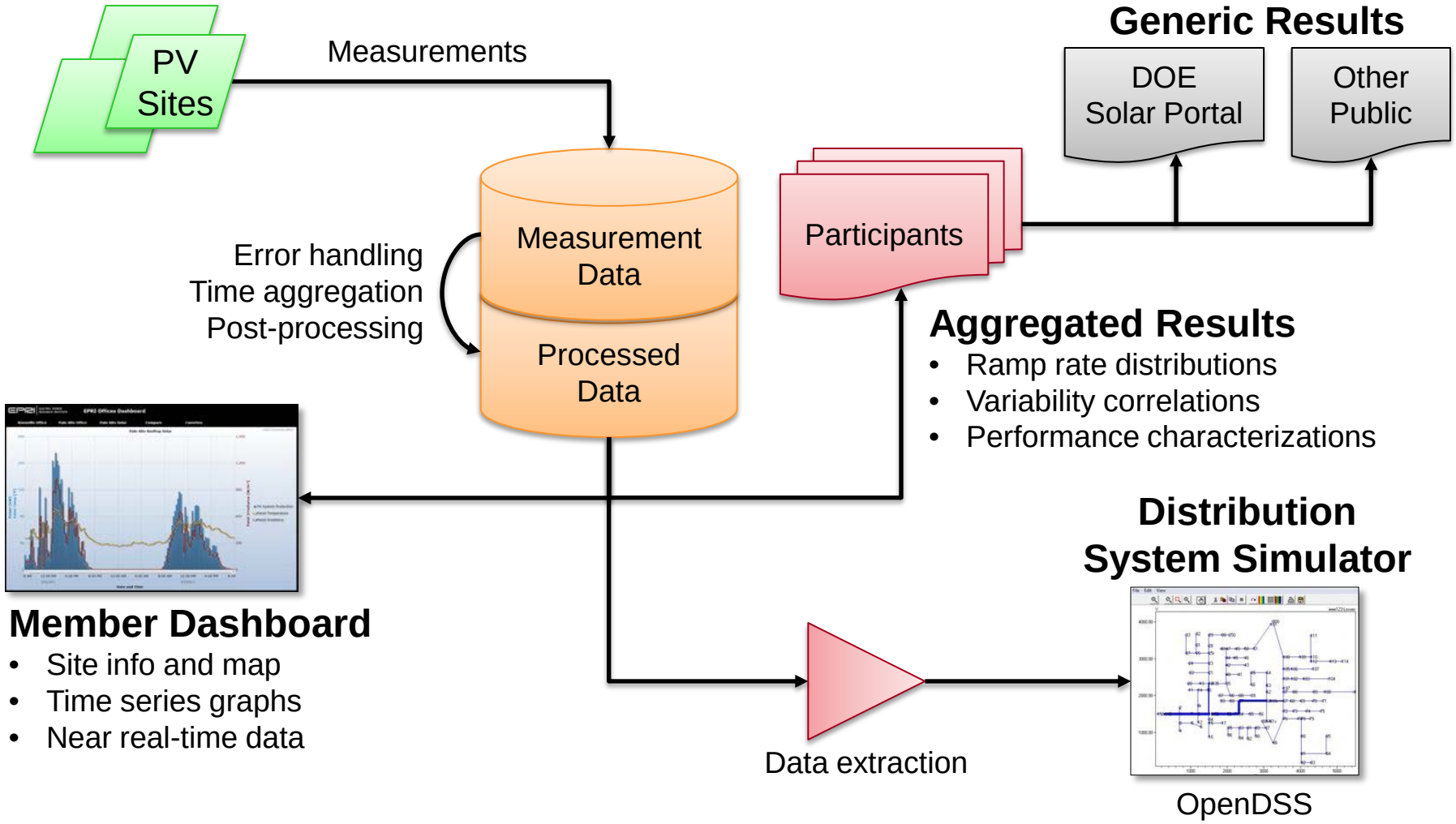
High Resolution Field Data & Geospatial Analytics

Distributed PV Monitoring supports EPRI's core PV research areas



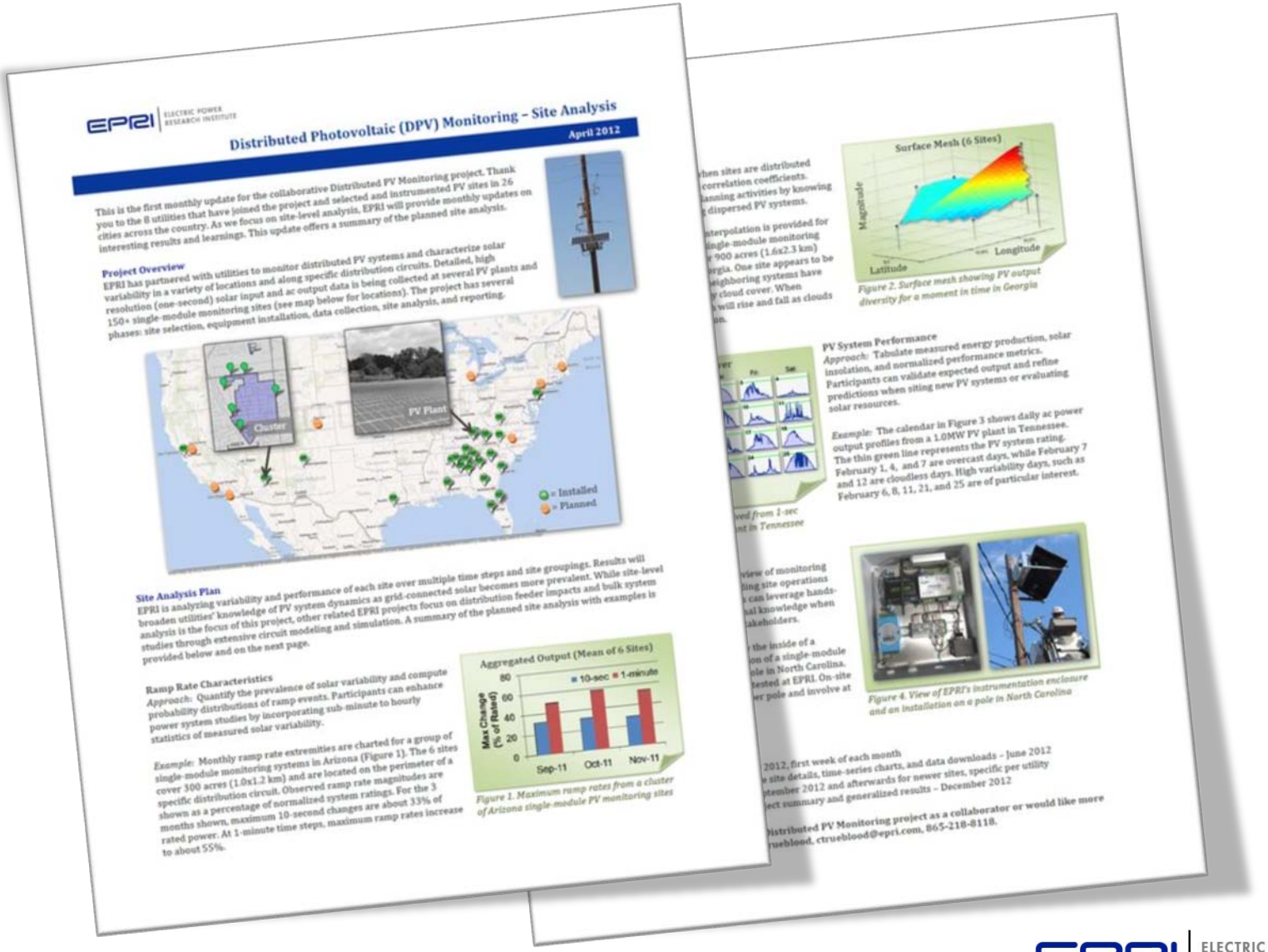
Analysis and Reporting Plan - DPV Data Flow

Measurement data feeds website, site analysis, and OpenDSS



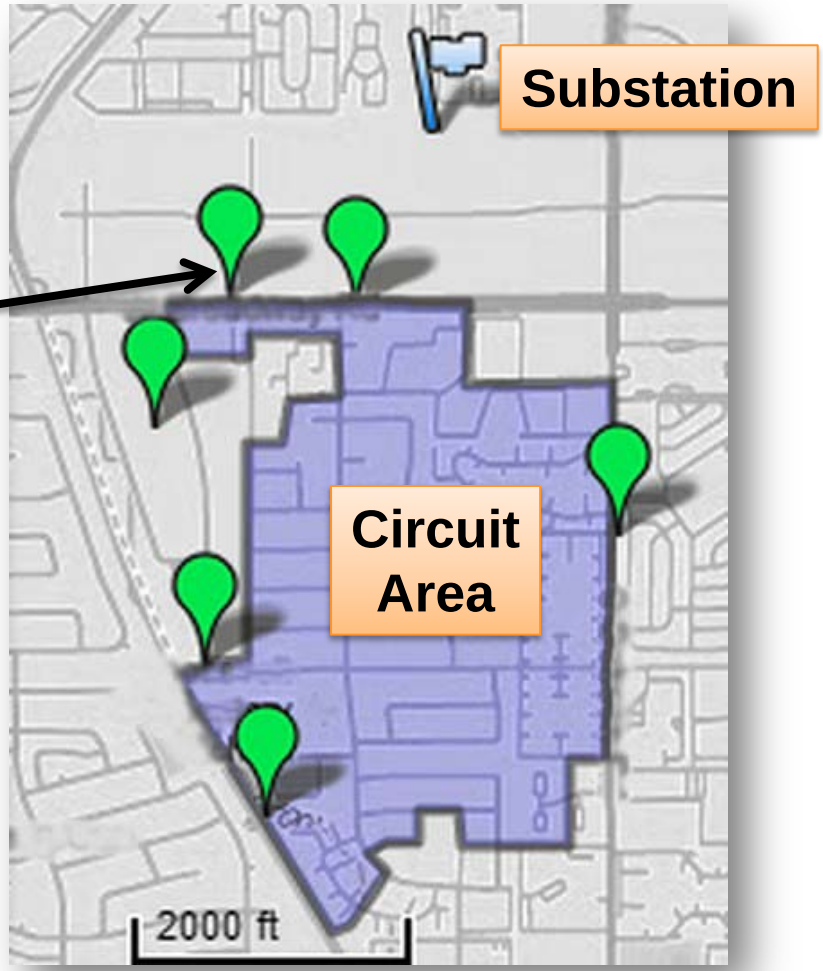
Site Analysis of Distributed PV Systems

Many sites have 1+ year of field data, ripe for site-level analysis



Distributed pole-mount PV sites in Arizona

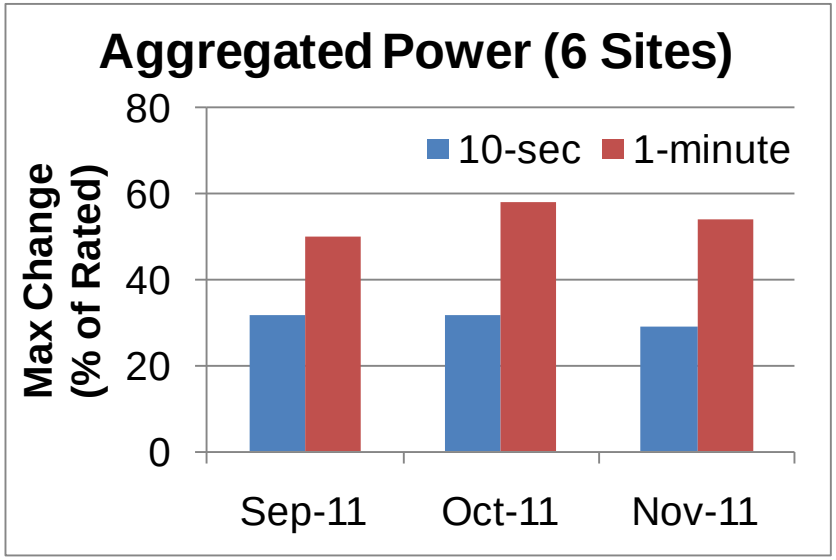
Six single-module systems installed, data collection began June 2011

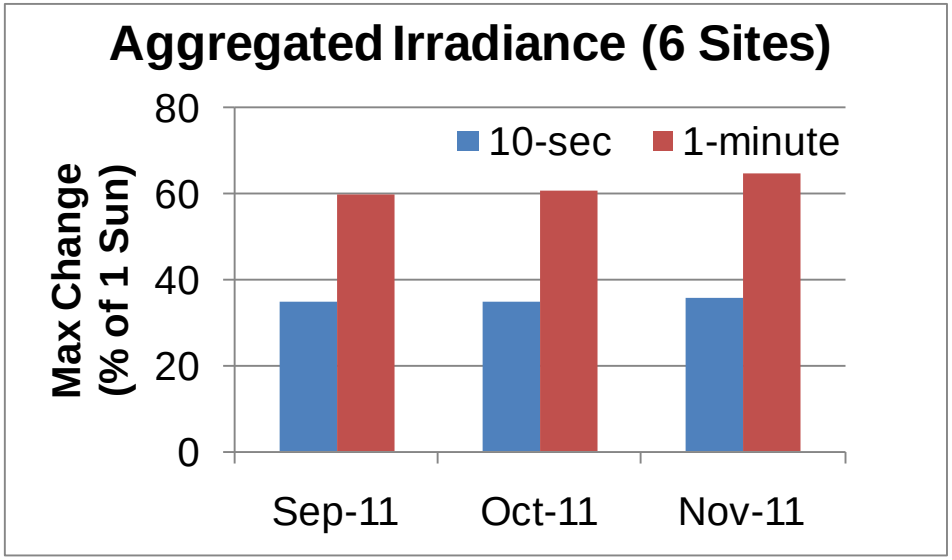


Daily Maximum Changes in Power, Irradiance

Aggregated from 6 pole-mount PV sites on an Arizona distribution circuit

- **Aggregated Power (from six 190W PV modules)**
  - Max 10-sec change about **30%** of rated power
  - Max 1-minute change about **55%** of rated power
- **Aggregated Irradiance (plane-of-array pyranometers)**
  - Max 10-sec change about **35%** of full sun (1000 W/m^2)
  - Max 1-minute change about **60%** of full sun





Max changes in power/irradiance are consistent across fall months Sept-Nov 2011

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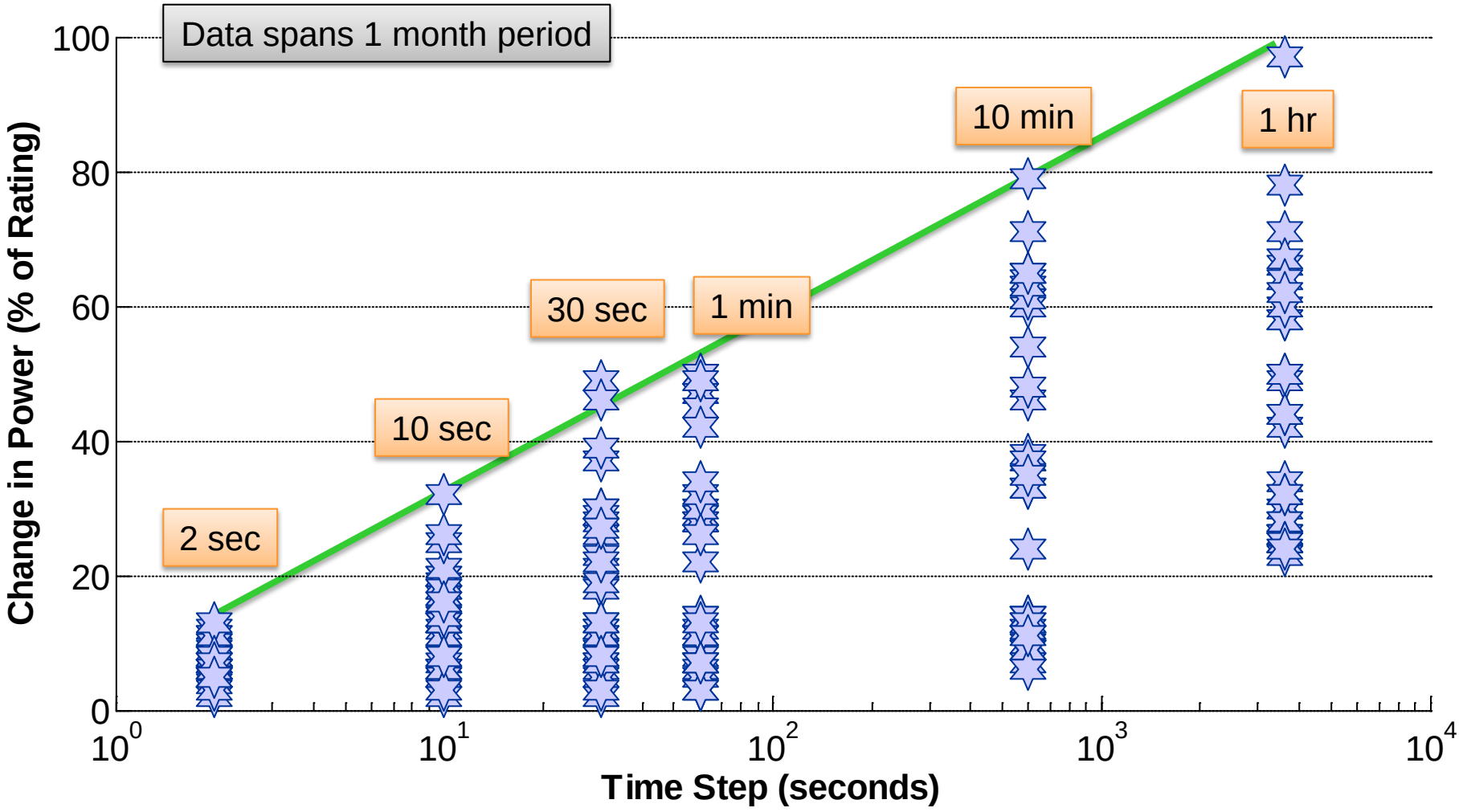
Daily Maximum Changes in AC Output Power

Aggregated from 6 pole-mount PV sites on an Arizona distribution circuit



1MW PV System in Tennessee

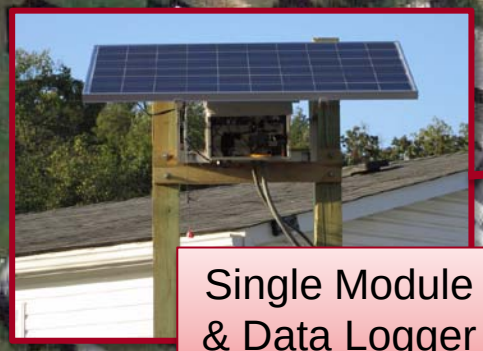
Solar resource and AC output recorded at 1-sec resolution

1.0 MW_{dc}

- 3.5 acre property
- 4,608 PV modules
- Four 260kW inverters
- Installed Aug 2010
- Data began Oct 2011

8 Pyranometers

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



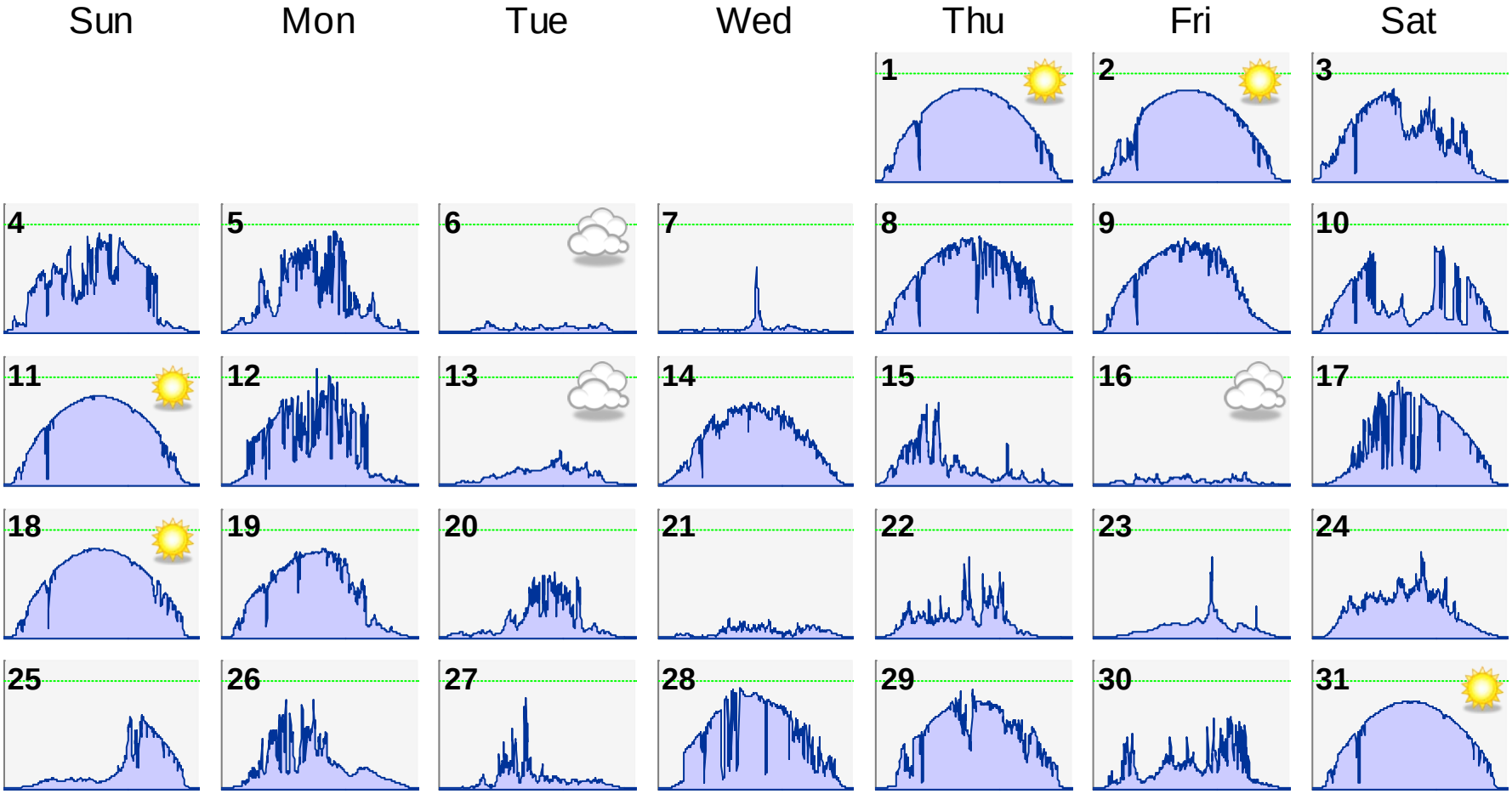
Single Module & Data Logger

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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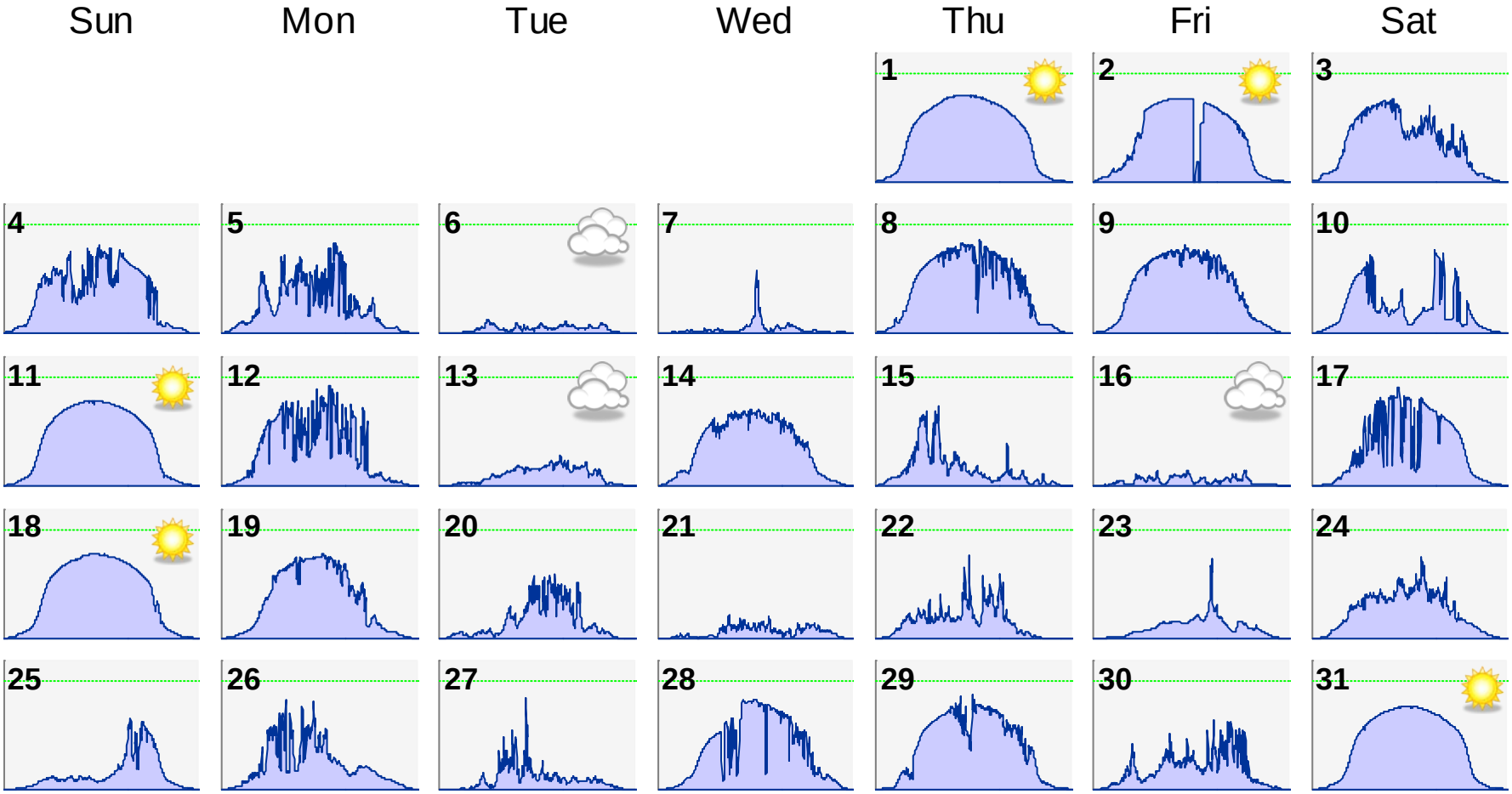
Solar Resource Calendar – 1MW$_{AC}$ Output Power

December 2011 at 1MW PV site in Tennessee

December 2011: Tennessee 1MW PV System Power



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

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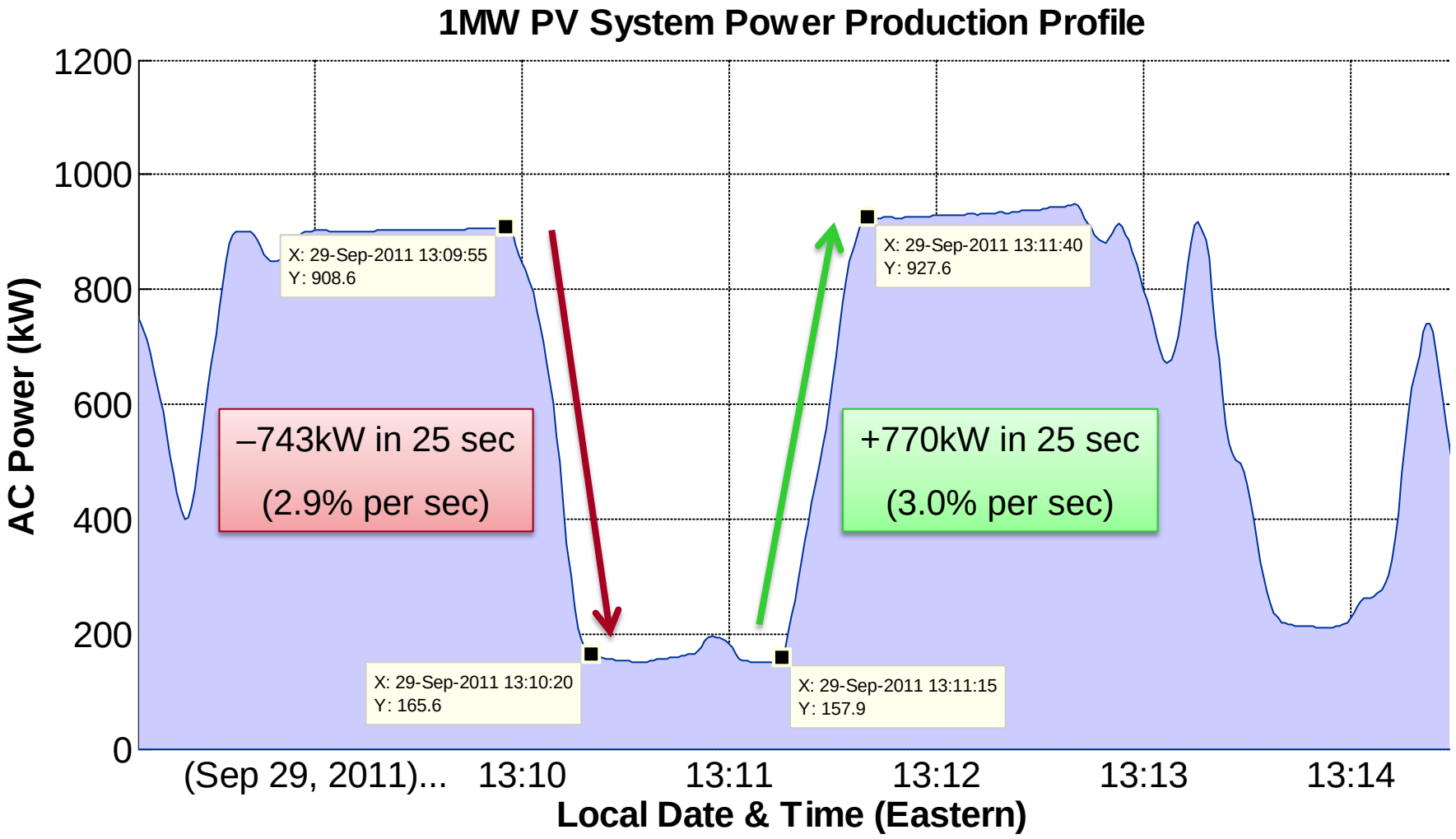
Example Ramp Events on Partly Cloudy Day

Six-minute view of AC power profile of 1MW system at 1-sec resolution



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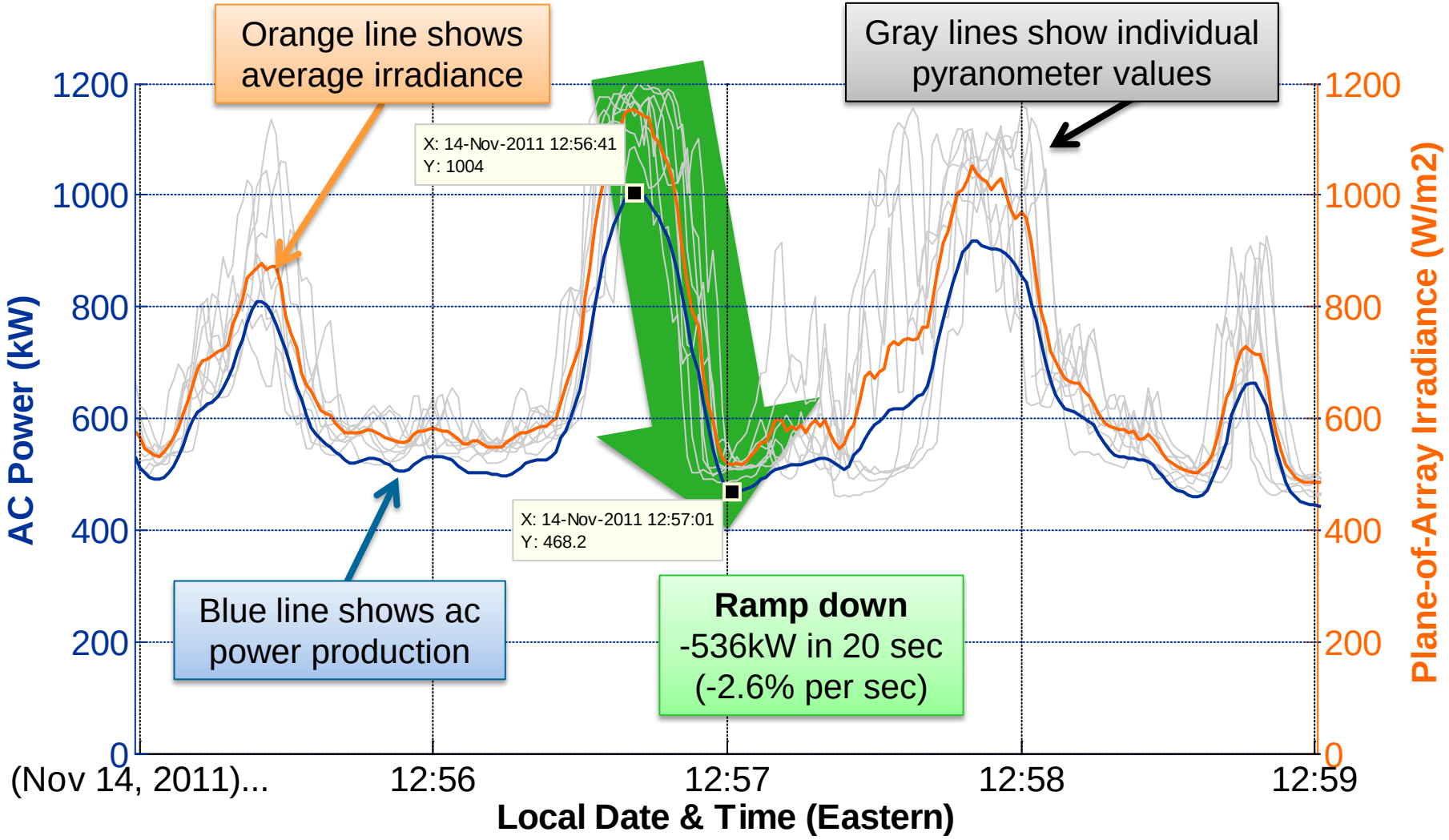
AC Power and Irradiance on Partly Cloudy Day

4-minute period shows time-shifted effect of passing clouds over 1MW



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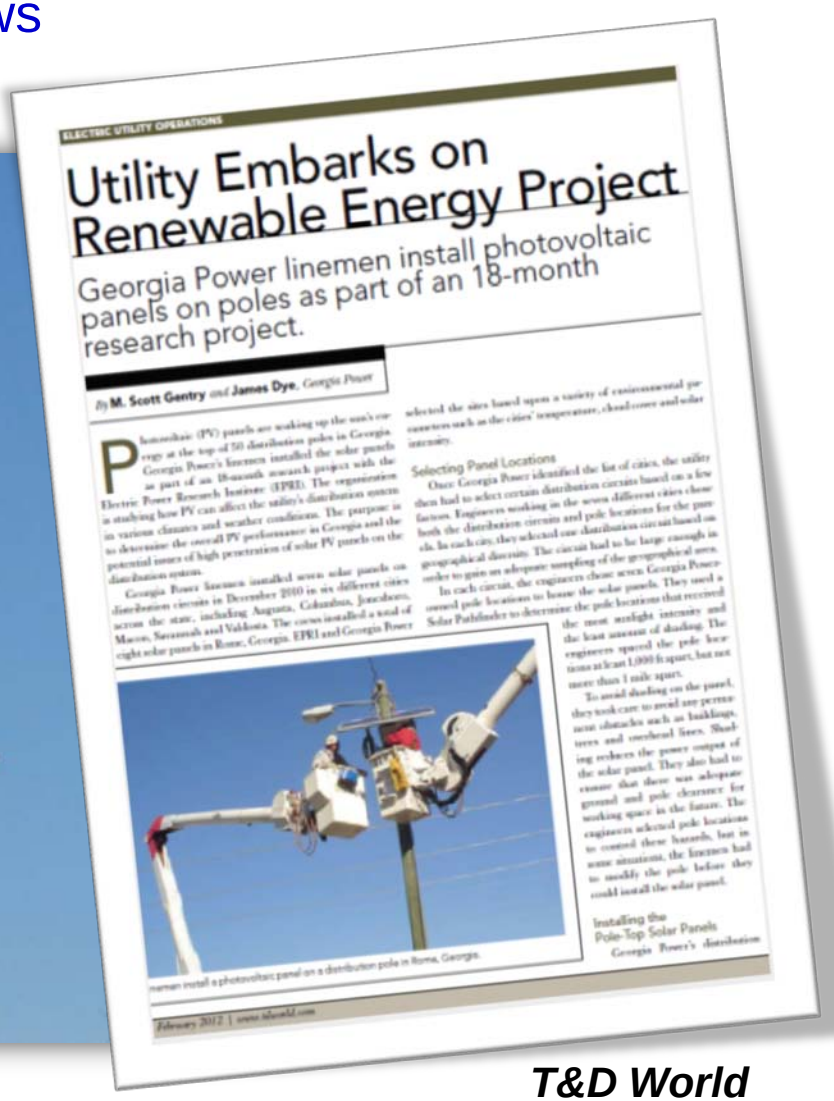
Added Value with Utility Line Crew Participation

Hands-on approach yields PV savvy crews

Georgia Power installs project's first pole-mount systems in Dec 2010



ELECTRIC UTILITY OPERATIONS

Utility Embarks on Renewable Energy Project

Georgia Power linemen install photovoltaic panels on poles as part of an 18-month research project.

By M. Scott Gentry and James Dye, Georgia Power

Photovoltaic (PV) panels are soaking up the sun's energy at the top of 50 distribution poles in Georgia. Georgia Power's linemen installed the solar panels as part of an 18-month research project with the Electric Power Research Institute (EPRI). The organization is studying how PV can affect the utility's distribution system in various climates and weather conditions. The purpose is to determine the overall PV performance in Georgia and the potential issues of high penetration of solar PV panels on the distribution system.

Georgia Power linemen installed seven solar panels on distribution circuits in December 2010 in six different cities across the state, including Augusta, Columbus, Jonesboro, Macon, Savannah and Valdosta. The crews installed a total of eight solar panels in Rome, Georgia. EPRI and Georgia Power selected the sites based upon a variety of environmental parameters such as the cities' temperature, cloud cover and solar intensity.

Selecting Panel Locations

Once Georgia Power identified the list of cities, the utility then had to select certain distribution circuits based on a few factors. Engineers working in the seven different cities chose both the distribution circuits and pole locations for the panels. In each city, they selected one distribution circuit based on geographical diversity. The circuit had to be large enough in order to gain an adequate sampling of the geographical area.

In each circuit, the engineers chose seven Georgia Power-owned pole locations to house the solar panels. They used a Solar Pathfinder to determine the pole locations that received the most sunlight intensity and the least amount of shading. The engineers spaced the pole locations at least 1,000 ft apart, but not more than 1 mile apart.

To avoid shading on the panel, they took care to avoid any permanent obstacles such as buildings, trees and overhead lines. Shading reduces the power output of the solar panel. They also had to ensure that there was adequate ground and pole clearance for working space in the future. The engineers selected pole locations to control these hazards, but in some situations, the linemen had to modify the pole before they could install the solar panel.

Installing the Pole-Top Solar Panels

Georgia Power's distribution

lineman install a photovoltaic panel on a distribution pole in Rome, Georgia.

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