Solar Research at BNL

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October 10, 2012

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

LISF Overview…

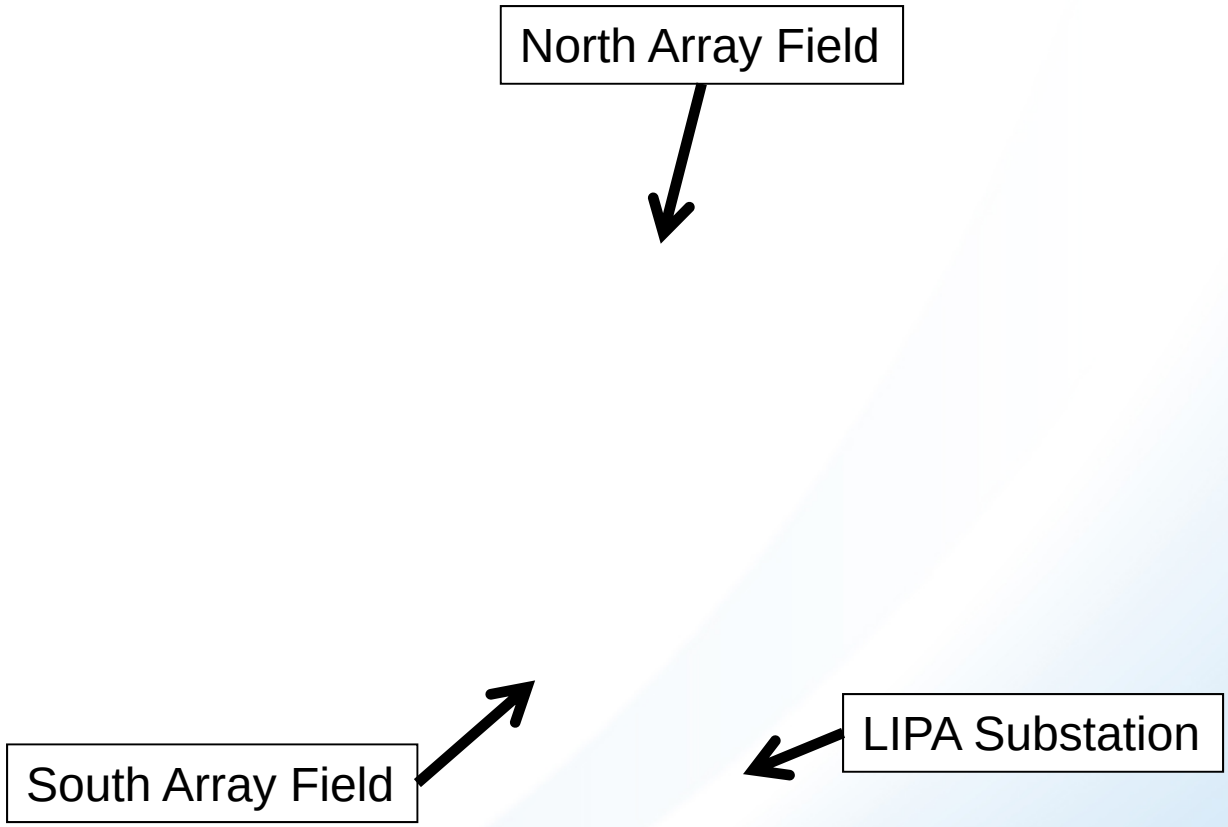
- LIPA Issued Solar RFP on April 22, 2008 which sought:
  - 50 MW or more of capacity, energy, and Renewable Energy Credits (RECs) from solar photovoltaic generating facilities (SGFs)
  - Capacity price, combined energy and REC price
  - Deliveries to commence at any time between May 1, 2009 and May 1, 2011
  - Contract terms of 5, 10, 15, or 20 years
- RFP Specified that SGFs:
  - Are to be located at non-residential customer sites in LIPA ‘s service territory
  - Have a minimum size of 100 kW (.1 MW) per site or 500 kW (.5 MW) in aggregate
  - Will be interconnected to LIPA’s T&D system with LIPA paying the interconnection costs
- 37 Proposals From 28 Proposers Received on August 14, 2008
  - 407 potential sites identified across Long Island
- LIPA’s Board of Trustees Selected 4 Proposers on December 17, 2009 and negotiated Power Purchase Agreements (PPA) with 2 Companies:
  - BP Solar to develop a 32MW project at Brookhaven National Laboratory
  - enXco to develop up to 17MW at Suffolk County-owned parking lots

LISF Overview…

- Project Developer/Owner/Operator
  - Long Island Solar Farm, LLC
- Purchaser of Power
  - Long Island Power Authority (LIPA)
    (via PPA)
- Project Host
  - U.S. Department of Energy at BNL
  - 20 yr easement granted for use of land
- Estimated Plant Lifetime
  - 30-40 years
- Construction Schedule
  - Fall 2010 – Early 2012
  - Completed Nov. 1, 2011

LISF Technical Specifications…

- Capacity
  - 32 MW (ac) delivered to LIPA
- PV Module Specifications
  - BP Solar Models BP3225T and BP3230T
  - Number: ~164,000
  - ~23 modules/string, ~7100 strings, ~290/inverter
  - Technology: Polycrystalline Silicon
- PV Module Installation:
  - Ground mounted, 24 panels/rack, ~7000 racks
  - Module Tilt: 27˚ Fixed; Array Azimuth: 180˚
- Inverter Power Blocks:
  - Manufacturer: SMA Sunny Central 630HE
  - Net Nameplate Rating: 1.25MW


North Array Field
South Array Field
LIPA Substation

LISF plant as of December 15, 2010


CAT
CATERPILLAR
319D
CAT

LISF as of May 11, 2011

LISF as of May 11, 2011

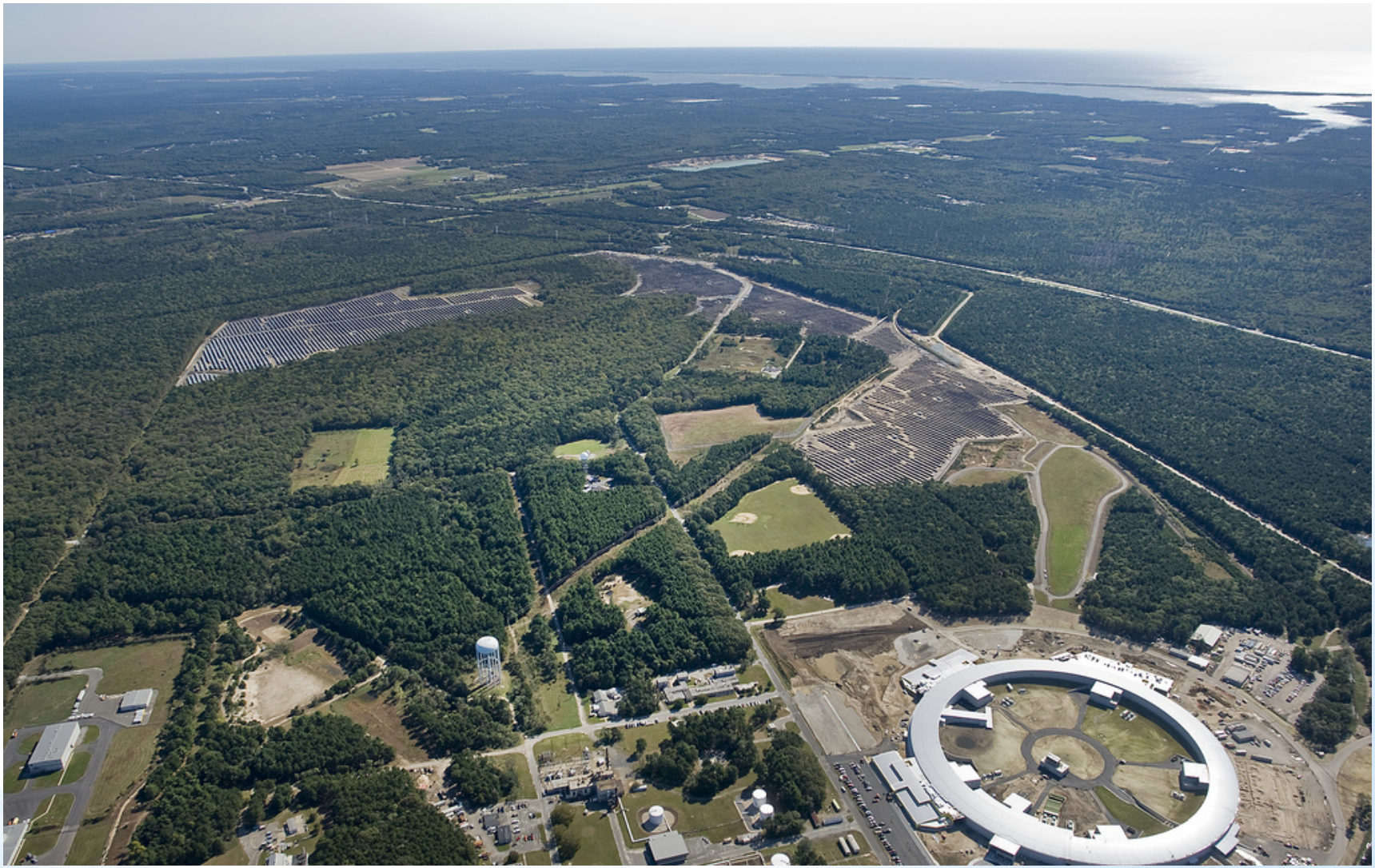
LISF as of June 9, 2011

- Piles 91% complete – 13,700 of 14,700 installed
- Racks 80% complete – 5,400 of 6,800 installed
- Modules 61% complete – 100,000 of 164,000 installed
- 13.8kV cable trenched and buried
- Inverters – 20 of 25 in place
- DC wiring – strings to combiner boxes started
- Substation transformer is in place
- Suppliers to start commissioning activities ~July
- Completion in fall 2011

Installation rate was 1000 panels/day
peaked at ~2000 panel/day in July/August

LISF as of June 30, 2011

LISF as of October 6, 2011



Aerial view from south of completed LISF – October 2011

To achieve the technical goals, research instrumentation was integrated into the LISF plant design *from the outset*…

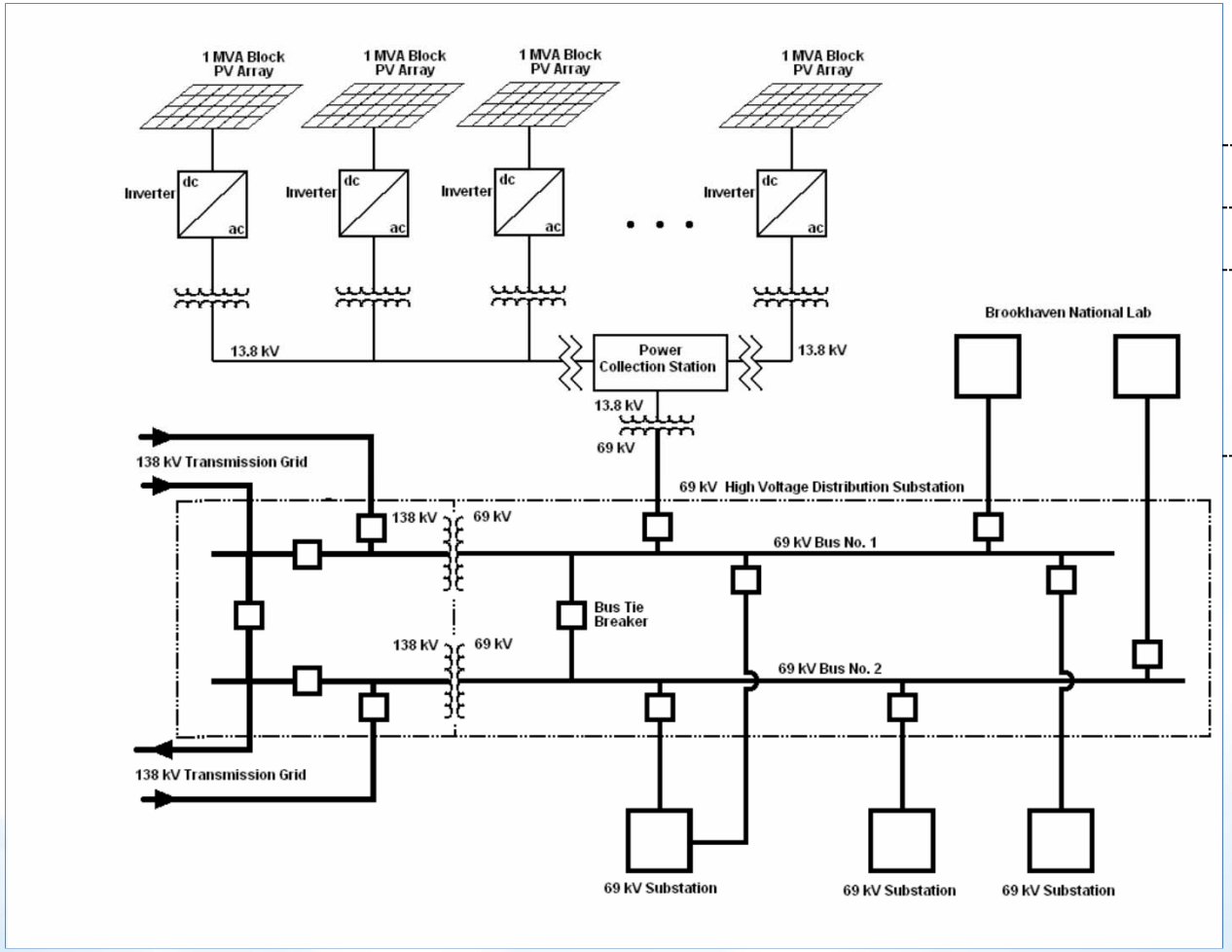
- BNL worked with BP Solar to incorporate advanced instrumentation into the array
- Modified Inverters at the factory
- Special piles and brackets to hold weather instrumentation
  - Power measurements at the string level ⇒ unprecedented spatial resolution (~1 rack)
  - Solar insolation data at each inverter power block ⇒ unprecedented spatial resolution
  - Research instrumentation ⇒ unprecedented temporal resolution
    - Solar Resource Data: sample rates up to 1 per second
    - Meteorological Data: sample rates up to 1 per second
    - Power Quality Data: sample rates up to 512 per cycle
- All data will be time synchronized across the field

Solar Irradiance and Meteorological Data is being collected…

- Field-based pyranometers: 32 pairs to measure direct and diffuse irradiance at each inverter node covering the entire array
- Baseline irradiance: precise measurement of solar irradiance at base station to quantify uncertainties in field data
  - *Solar tracking measurements*
  - *Rotating shadowband radiometer*

- Meteorological measurements:
  - *Temperature (air and panel)*
  - *Relative Humidity*
  - *Barometric Pressure*
  - *Wind speed and direction*
  - *Rain gauge*
- Total Sky Imagers

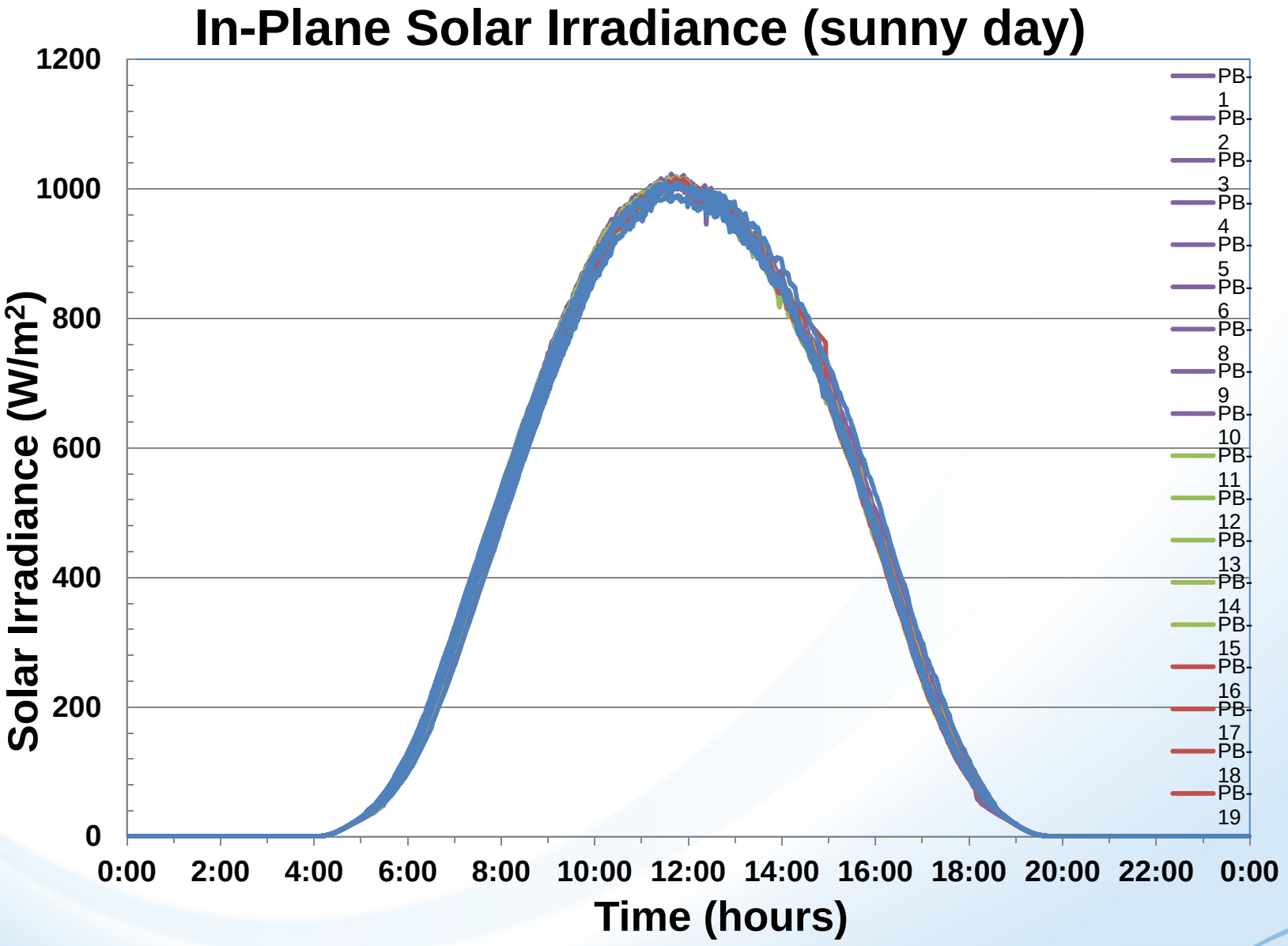
Power Quality data will be collected at high speed (512 cycles per second)…

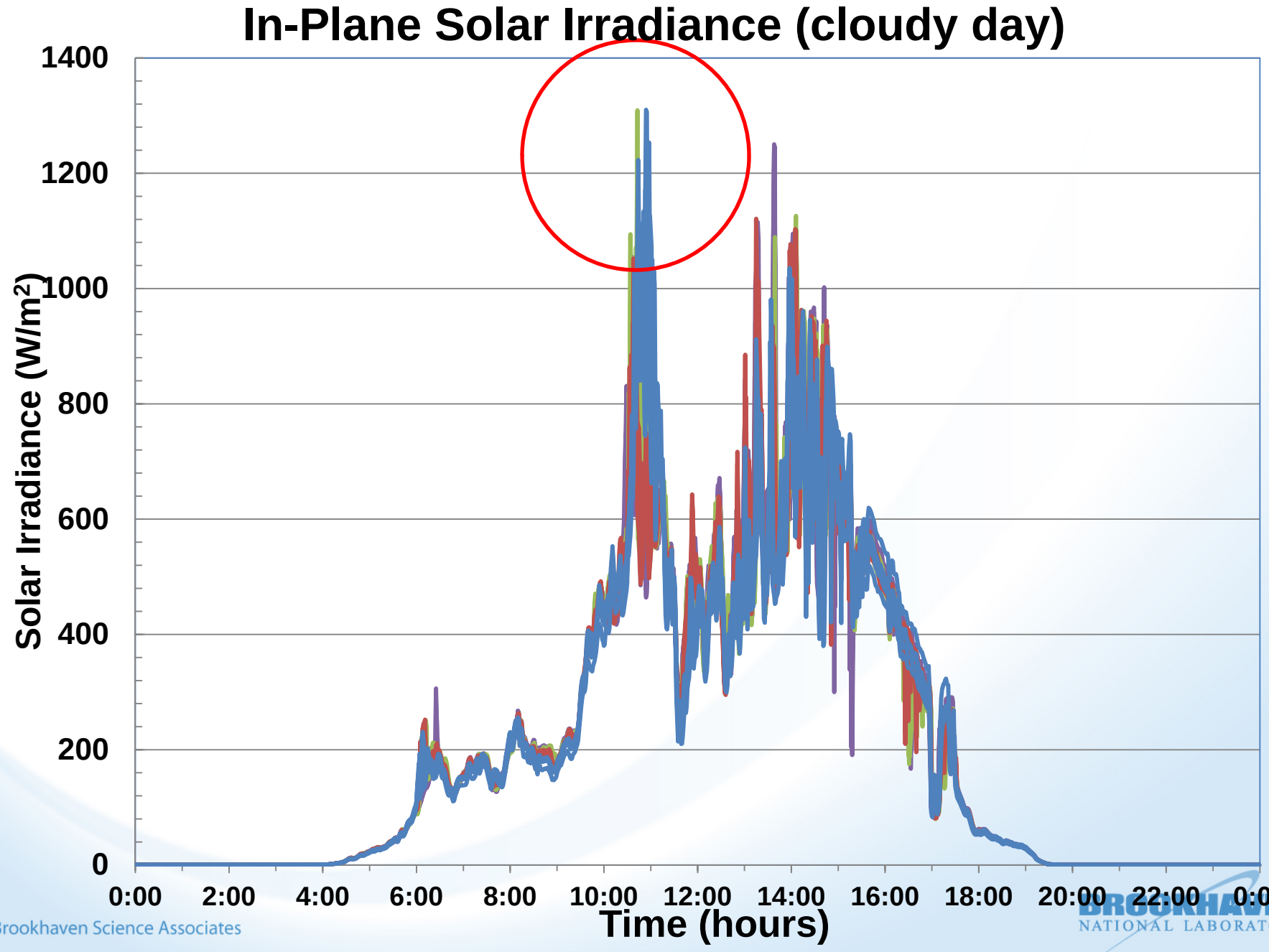


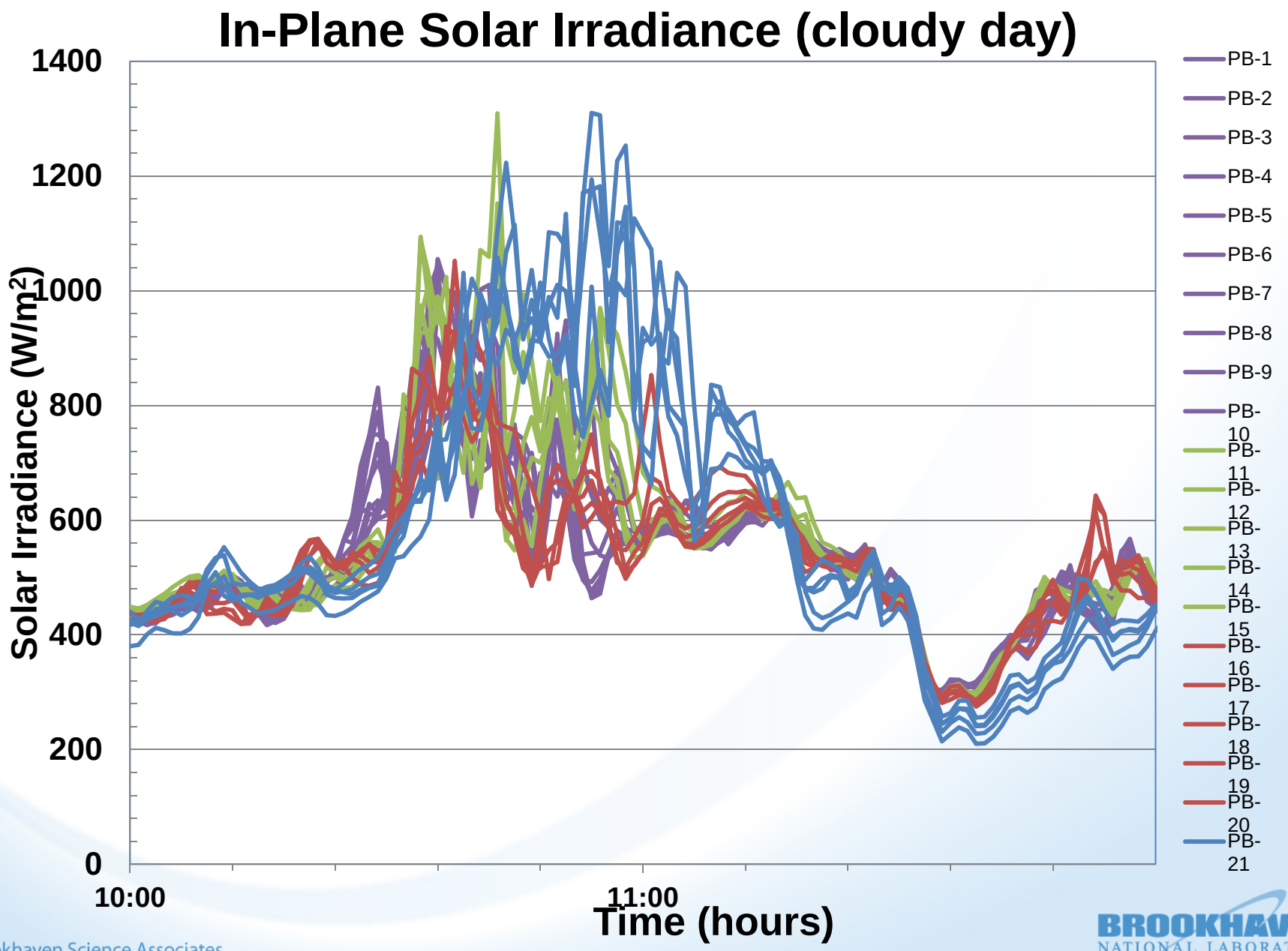
Data Acquisition System
- Power Quality

<u>Power Quality Data</u>

- String level
- Inverters
- Array Substation
- LIPA Feeders to BNL

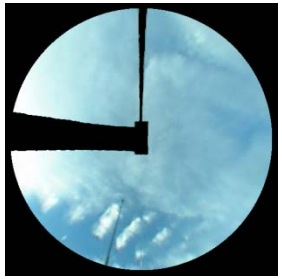

In-Plane Solar Irradiance (sunny day)
Solar Irradiance (W/m²)
1200
1000
800
600
400
200
0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time (hours)
PB 1
PB 2
PB 3
PB 4
PB 5
PB 6
PB 8
PB 9
PB 10
PB 11
PB 12
PB 13
PB 14
PB 15
PB 16
PB 17
PB 18
PB 19


In-Plane Solar Irradiance (cloudy day)
Solar Irradiance (W/m²)
1400
1200
1000
800
600
400
200
0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time (hours)

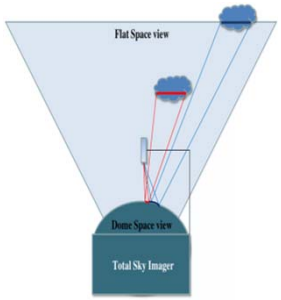

In-Plane Solar Irradiance (cloudy day)
Solar Irradiance (W/m2)
1400
1200
1000
800
600
400
200
0
10:00
11:00
Time (hours)
PB-1
PB-2
PB-3
PB-4
PB-5
PB-6
PB-7
PB-8
PB-9
PB-10
PB-11
PB-12
PB-13
PB-14
PB-15
PB-16
PB-17
PB-18
PB-19
PB-20
PB-21

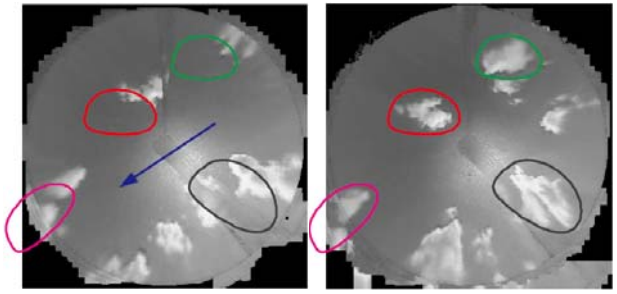
Near Term Prediction of Solar Resources

TSI output image



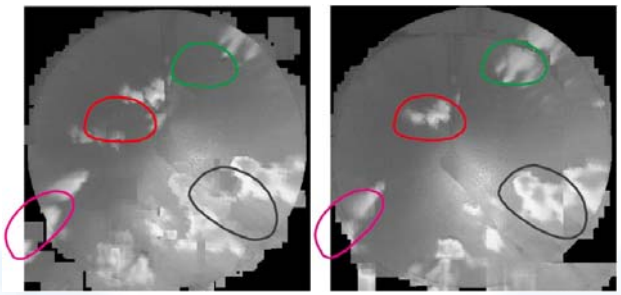
Preprocessed TSI Image





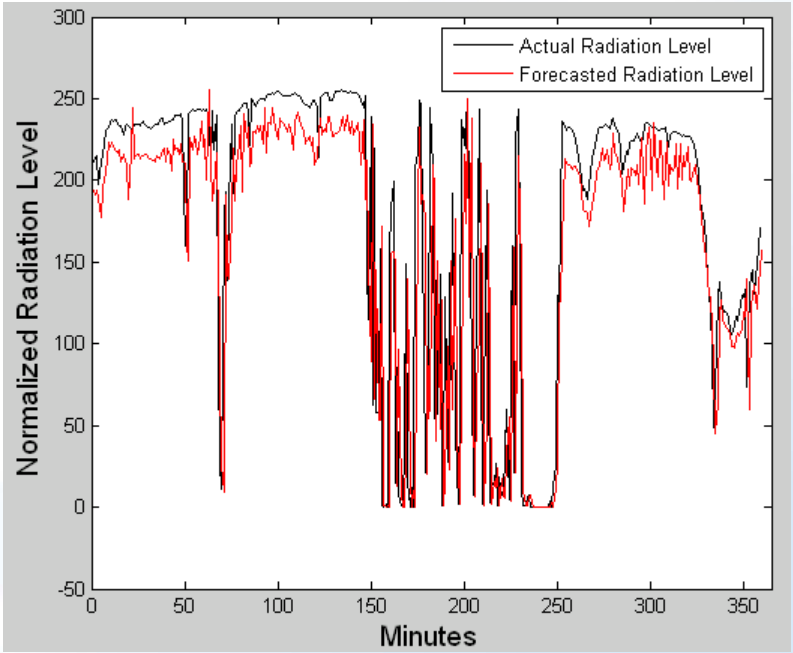
Most current image

Future image
(estimation target)



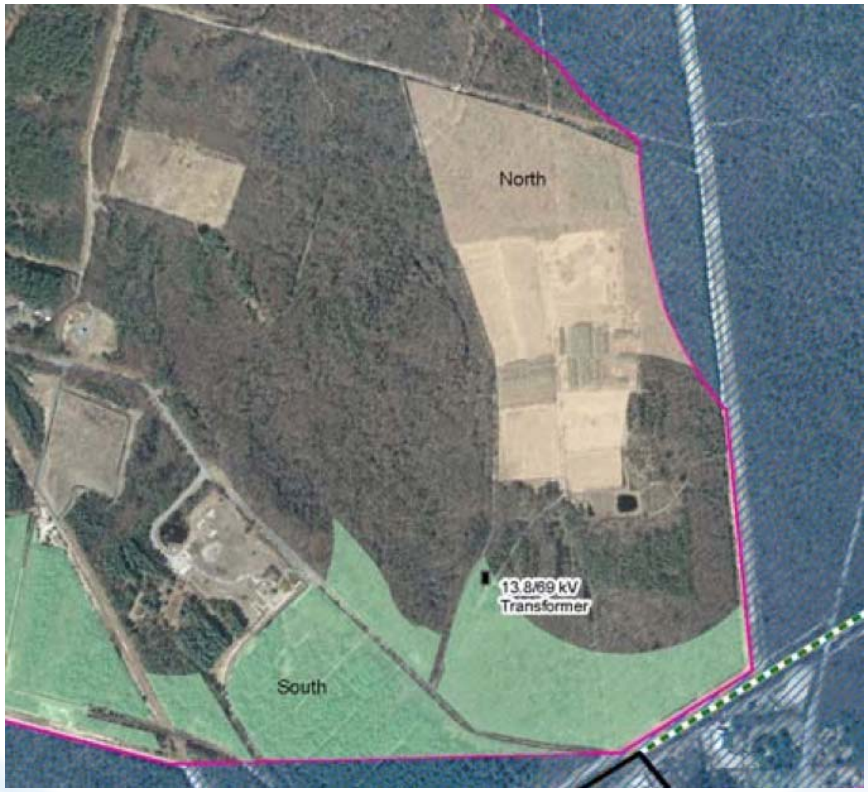
Simple estimation result

Our final estimation result



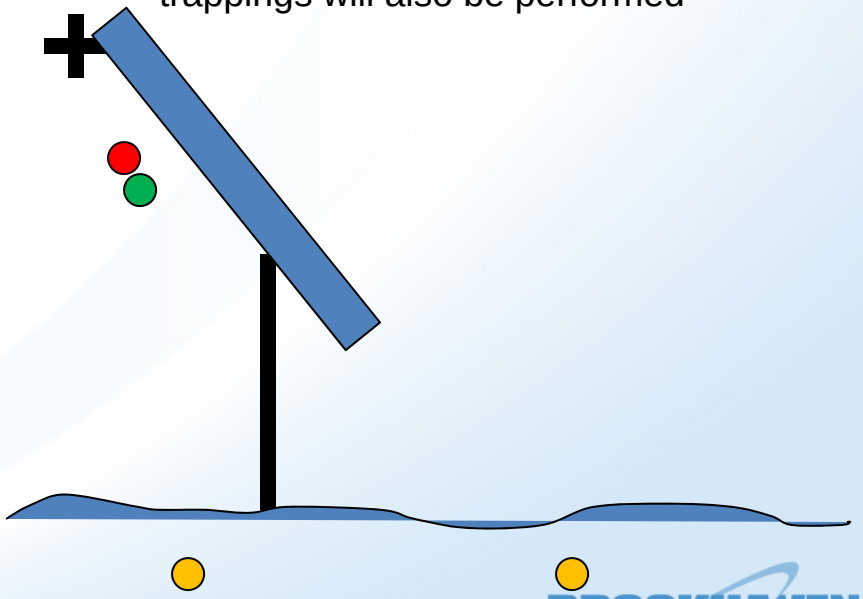
Environmental monitoring instruments for research purposes…

North array only



- Relative Humidity (at 10 locations in north array)
- Soil Temperature (2 at 10 locations in north array)
- Air Temperature below panel (at 10 locations in north array)

* Data from the BNL Met instruments, along with mobile instruments and animal trappings will also be performed



BNL is also proceeding with development of a Northeast Solar Energy Research Center (NSERC)

- Supplement research using the LISF array
  - Dedicated research array for field testing (up to 1MW)
  - Laboratory space for standardized testing
- NSERC will enable research in various other areas of interest to the DOE and the solar industry
  - Field testing under actual northeast conditions
- Energy would be delivered directly into the BNL electrical system
  - Supports BNL sustainability goals

Research Agenda for NSERC

- Smart Grid Integration Studies
  - Techniques for management of circuits with high penetration of DG
  - Power quality issues
  - Role of renewables in micro-grid design, control
- Field Testing of New Technologies
  - Evaluation of ‘new design concepts: inverters w/ voltage regulation and VAR control
  - Evaluation of different electrical conversion topologies (multi-level inveters)
  - Performance of 3rd gen PV in northeast (e.g. CIGS)
- Reliability and Degradation Studies
  - Field testing/ reliability and degradation studies in NE
  - Accelerated lifetime/standardized test conditions to evaluate component degradation
  - Post mortem testing and failure analyses
- High penetration of DG on distribution feeders
  - Studies of stability and control
  - Value propositions for integrated grid-level storage

The research array will be located across from NSLS-II in 3 areas comprising ~6.5 acres of land