Solar Research at BNL

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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
LIPA Substation
South Array Field
LISF plant as of December 15, 2010
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

- Power Quality Data
  - String level
  - Inverters
  - Array Substation
  - LIPA Feeders to BNL
In-Plane Solar Irradiance (cloudy day)

Solar Irradiance (W/m²)

Time (hours)
In-Plane Solar Irradiance (cloudy day)

Solar Irradiance (W/m²) vs. Time (hours)

PB-1 to 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

![Graph showing Actual Radiation Level and Forecasted Radiation Level over time]
Environmental monitoring instruments for research purposes...

- 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 inverters)
  - 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.