## CPET 581 Smart Grid & Energy Management Friday 6:00-8:45PM 2013/11/8

## Lecture 14

## **Topics of Discussion**

- (1) Solar Power Systems and System Integration
  - Solar Research, Major Research Laboratories
  - Solar System Engineering, Design, Integration
  - Solar Energy Storage
  - PV Testing Equipment
  - Solar Energy Estimation, Performance Estimation Software Tools
- (2) Energy Efficiency Management & Smart Building
  - Cutting Energy Cost with Hierarchical Control, Vol. 1, No. 1, IEEE Electrification Magazine, Sept. 2013, <a href="https://www.ieee-pes.org">www.ieee-pes.org</a>
  - Energy Management, Building Automation Systems, U of I
  - Building Automation for Enhanced Energy and Operational Efficiency, http://www.ti.com/lit/wp/spry247/spry247.pdf
  - Occupancy-Driven Energy Management for Smart Building, <a href="http://synergy.ucsd.edu/yuvraj/docs/Agarwal BuildSys10">http://synergy.ucsd.edu/yuvraj/docs/Agarwal BuildSys10</a> Occupancy.pdf
  - Building Automation & Energy Management & Control
  - Energy Management Services, <a href="http://us.sunpowercorp.com/power-plant/products-services/services/">http://us.sunpowercorp.com/power-plant/products-services/</a>
  - Eaton Energy, http://www.eaton.com/Eaton/ProductsbyMarket/Energy/index.htm
- (3) Solar Energy Links, U.S. Bureau of Land Management, http://www.blm.gov/wo/st/en/prog/energy/solar energy.html
- (4) Other References
- Solar PV On Campus Database, The Association for the Advancement of Sustainability in Higher Education, <a href="http://www.aashe.org/resources/campus-solar-photovoltaic-installations/">http://www.aashe.org/resources/campus-solar-photovoltaic-installations/</a>
  - 322 campuses in 45 states, total capacity 183,747 kW (183 MW), and the average capacity is 344 kW.
  - 3 MW Solar PV, 2010, William Paterson University, NJ
  - Arizona State University, Solar Initiatives, http://www.asu.edu/tour/sustainability/solar.html
    - TUV Rheinland Photovoltaic Testing Laboratory, <u>http://www.asu.edu/tour/sustainability/tuv-ptl.html</u>

- Solar College Initiatives, <a href="http://www.solarcampusinitiative.org/">http://www.solarcampusinitiative.org/</a>
- Solar PV Laboratories
- NREL Solar Research, http://www.nrel.gov/solar/
  - Solar Radiation Research
  - Solar Thermal Research
  - Solar Heating
  - Solar Systems Integration
    - Distributed Grid Integration, http://www.nrel.gov/electricity/distribution/
    - Transmission Grid Integration, http://www.nrel.gov/electricity/transmission/
    - System Advisor Model (SAM), <a href="https://sam.nrel.gov/">https://sam.nrel.gov/</a>
    - PV Engineering, <a href="http://www.nrel.gov/pv/engineering.html">http://www.nrel.gov/pv/engineering.html</a>
    - PV performance reliability and safety, http://www.nrel.gov/pv/performance reliability/
    - Solar source assessment, <a href="http://www.nrel.gov/solar radiation/">http://www.nrel.gov/solar radiation/</a>
    - Technology system analysis, http://www.nrel.gov/analysis/tech\_analysis.html
- Sandia National Laboratories Photovoltaics, <a href="http://energy.sandia.gov/?page\_id=2727">http://energy.sandia.gov/?page\_id=2727</a>
- MIT PV Research Lab, <a href="http://pv.mit.edu/">http://pv.mit.edu/</a>
- Renewable Energy & Smart Grid, FSI Stanford, <a href="http://pesd.stanford.edu/research/low carbon electricity/">http://pesd.stanford.edu/research/low carbon electricity/</a>
- The Open PV Project, <a href="https://openpv.nrel.gov/">https://openpv.nrel.gov/</a>
  - The real-time status of solar PV market in U.S.: Total # of installs: 235, 919, Cost \$/W (2013) 4.47, Capacity (MW) 5463.67
  - Search for State
- Solar Estimator, <a href="http://www.solar-estimate.org/?page=rightforme">http://www.solar-estimate.org/?page=rightforme</a>
- Clean Power Estimator, <u>http://www.gosolarcalifornia.org/tools/clean\_power\_estimator.php</u>
- Solar PV
- U.S. DOE Solar Decathlon, <a href="http://www.solardecathlon.gov/">http://www.solardecathlon.gov/</a>
- PV Testing Equipment
  - http://www.seawardgroupusa.com/userfiles/pv150.php?utm source=google&utm medium=cpc&u tm campaign=solar
    - Ground continuity
    - Insulation resistance
    - Polarity
    - Open circuit voltage
    - DC operating power
    - Ground test lead null
    - Short circuit current

- Operational current
- Irradiance
- Temperature
- http://www.solar-pv-tester.com/
- Solar Power System + Substation Integration,
  - AETI (American Electric Technologies), Solar Inversion System http://www.aeti.com/solarsolutions
    - 1000V 1.0 & 1.5 MW 15kV
    - UL 1741 Integrated Solar Inversion Stations (ISI);
    - 1000V 15 or 38kV collection grid or substation utility interconnection system,
- Solar power systems & Integration
  - System Integration, <a href="http://www1.eere.energy.gov/solar/pdfs/46663.pdf">http://www1.eere.energy.gov/solar/pdfs/46663.pdf</a>
  - Solar Energy Technologies Program, <u>http://www1.eere.energy.gov/solar/pdfs/47282.pdf</u>
  - Solar Energy Grid Integration Systems (SEGIS), Oct. 2007, <a href="http://www1.eere.energy.gov/solar/pdfs/segis-concept-paper.pdf">http://www1.eere.energy.gov/solar/pdfs/segis-concept-paper.pdf</a>
- Integrated Substation Automation System Design, 2001, <a href="http://tdworld.com/archive/integrated-substation-automation-system-design">http://tdworld.com/archive/integrated-substation-automation-system-design</a>
- NREL Distributed Grid Integration, <a href="http://www.nrel.gov/electricity/distribution/">http://www.nrel.gov/electricity/distribution/</a>
  - Codes & Standards,

http://www.nrel.gov/electricity/distribution/projects codes standards.html

- IEEE 1547 Family of standards
- IEEE 2030 Family of standards
- Data Collection & Visualization,

http://www.nrel.gov/electricity/distribution/projects data collection.html

- Hawaii Clean Energy Initiative, <u>http://www.nrel.gov/electricity/distribution/projects\_hcei.html</u>
- Microgrids,

http://www.nrel.gov/electricity/distribution/projects microgrid.html

- Power System Modeling,
  - http://www.nrel.gov/electricity/distribution/projects power systems.html
- Solar Distributed Grid Integration,
  - http://www.nrel.gov/electricity/distribution/projects\_solar.html
- Technology Development,
  - http://www.nrel.gov/electricity/distribution/projects technology developme nt.html
    - High Penetration Photovoltaics,
       <a href="http://www.nrel.gov/electricity/distribution/projects\_high\_pen.html">http://www.nrel.gov/electricity/distribution/projects\_high\_pen.html</a>
    - Hydrogen System Research,
       <a href="http://www.nrel.gov/electricity/distribution/projects">http://www.nrel.gov/electricity/distribution/projects</a> hydrogen.html
    - Metering Solutions,
       <a href="http://www.nrel.gov/electricity/distribution/projects">http://www.nrel.gov/electricity/distribution/projects</a> metering.html

- Mobile Electric Power (US Army),
   <a href="http://www.nrel.gov/electricity/distribution/projects">http://www.nrel.gov/electricity/distribution/projects</a> mobile.html
- Vehicle-to-Grid,
   <a href="http://www.nrel.gov/electricity/distribution/projects-vehicle-grid.html">http://www.nrel.gov/electricity/distribution/projects-vehicle-grid.html</a>
- Wind2Battery, http://www.nrel.gov/electricity/distribution/projects wind2battery.html
- Projects
  - Solar Distributed Grid Integration Projects NREL, <u>http://www.nrel.gov/electricity/distribution/projects\_solar.html</u>
- Energy Storage
  - Battery Energy Storage for Enabling Distributed Solar Power Generation, <a href="http://www.me.utexas.edu/~apscl/pdf/GAIN%20-%20Hill.pdf">http://www.me.utexas.edu/~apscl/pdf/GAIN%20-%20Hill.pdf</a>
- Renewable Energy World, <u>www.renewableeneryworld.com</u>
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- Solar Power System Design
  - Solar Electric System Design, Operation and Installation, Oct. 2009, <a href="http://www.energy.wsu.edu/documents/solarpvforbuildersoct2009.pdf">http://www.energy.wsu.edu/documents/solarpvforbuildersoct2009.pdf</a>
  - Commercial Solar Power System Design and Installation, http://www.bluesel.com/solar-power-systems/
  - Design and Implementation of a Solar Power System, (M.S. Thesis), http://dspace.mit.edu/bitstream/handle/1721.1/32807/57587915.pdf
  - Solar Power System Modeling & Control (light sensor, diode, series, parallel),
     Paul Lin
- Papers
  - Control for Renewable Energy and Smart Grid, 2011, <a href="http://ieeecss.org/sites/ieeecss.org/files/documents/loCT-Part1-06RESG.pdf">http://ieeecss.org/sites/ieeecss.org/files/documents/loCT-Part1-06RESG.pdf</a>
- Software Tools
  - PVWatts Grid Data Calculator (Version 2), <u>http://www.nrel.gov/rredc/pvwatts/grid.html</u>
  - PVWatt Site Specific Data Calculator (Version 1), <u>http://www.nrel.gov/rredc/pvwatts/site\_specific.html</u>
  - A Performance Calculator for Grid-Connected PV System, <a href="http://rredc.nrel.gov/solar/calculators/pvwatts/version1/">http://rredc.nrel.gov/solar/calculators/pvwatts/version1/</a>
    - Fort Wayne Indiana,
       http://rredc.nrel.gov/solar/calculators/pvwatts/version1/US/Indiana/
      - http://rredc.nrel.gov/solar/calculators/pvwatts/version1/US/In diana/Fort\_Wayne.html
        - DC Rating (kW): 4 kW, DC to AC Derate Factor: 0.77, Array
           Type, Array Tilt (degree)
        - o AC Energy and Cost Saving