

CPET 581 Smart Grid & Energy Management
Friday 6:00-8:45PM
2013/11/1

Lecture 13
Solar Power, Smart Meter, AMI

Topics of Discussion

- Solar power, Smart grid
 - Grid-tied, Off-Grid solar electric power system
 - Solar-grid integration
 - Net-metered PV systems (no battery backup)
 - Smart Meter and Net Metering
 - PG&E,
<http://www.pge.com/en/myhome/customerservice/smartmeter/index.page>
 - Islanding capability with PV system
 - Ability for a PV system and the loads connected to it to be separated from the utility grid during outages so that no electricity could be fed into the grid and injured utility workers who are trying to repair down lines.
 - Grid-Tied Inverter
 - Sunny Central, www.SMA-America.com
 - Solectria Renewables, www.solren.com www.solrenview.com
 - American Solar Energy Society, <http://www.ases.org/>
International Solar Energy Society ([ISES](http://www.ases.org/))
Solar Electric Power Association ([SEPA](http://www.ases.org/))
The Solar Energy Industries Association ([SEIA](http://www.ases.org/))
- Smart Grid and Smart Meter Architecture, Tom Wilson, 011,
http://www.w4ar.com/smart_meter_wireless_safety_summit_Power_Pointe.pdf
- Advanced Metering Infrastructure (AMI) – Smart Grid Technology,
<http://www.ttiinc.com/docs/IO/24880/FCISmartMetersPresentation.pdf>
 - Smart Meter ⇔ Interface Protocol ⇔ Gate Way ⇔ Interface Protocol ⇔ Data Base
 - Typical AMI includes
 - Home networking system (communicating thermostats, and other in-home controls)
 - Smart meters
 - Communication networks from the meters to local data concentrators
 - Back-haul communications networks to corporate data centers
 - Meter data management system (MDSM) and
 - Data integration into existing and new software application platform
- Smart Meter, Technology
 - Types:
 - Time of Use (ToU) Meter
 - Interval Meter
 - Prepaid Meters
 - Numeric Token System
 - Smart Key System
 - Smart Card System

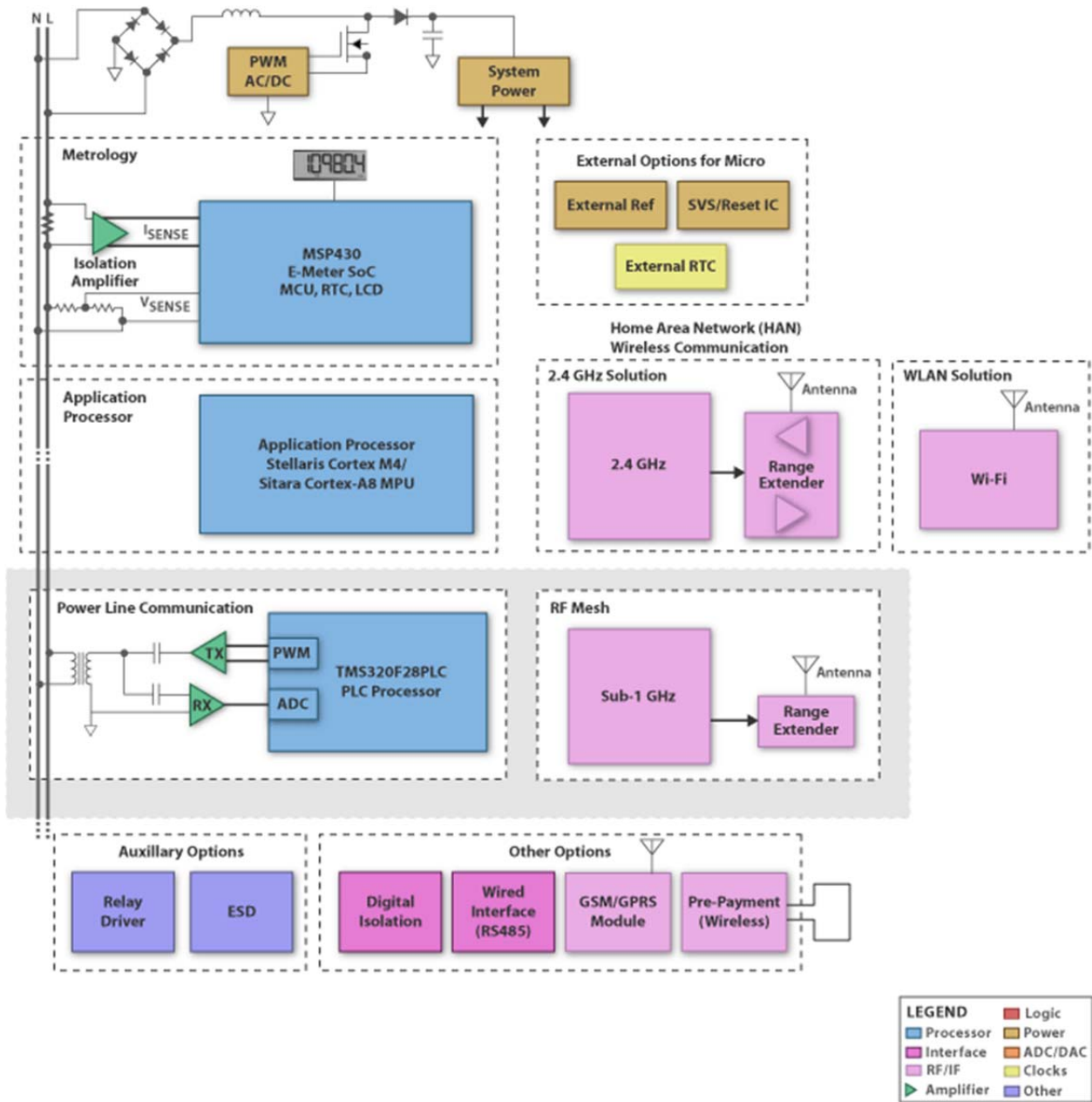
- Data Monitoring and Energy Analysis
- TI Smart Meter Solutions, [http://www.newark.com/pdfs/techarticles/ti/MeteringBrochure2H09SLYM071A\(2\).pdf](http://www.newark.com/pdfs/techarticles/ti/MeteringBrochure2H09SLYM071A(2).pdf)
- Smart Metering, July 2006, Distributed Generation, <http://www.leonardo-energy.org/sites/leonardo-energy/files/root/pdf/2006/SmartMetering.pdf>

Smart Meters

- CenterPoint Energy, <http://www.centerpointelectric.com/cehe/smartmeters/>
 - Energy InSight system: digital smart meters with two-way communication, <http://www.centerpointelectric.com/cehe/smartmeters/howtheywork/>
 -
- EKM Metering, <http://www.ekmmetering.com/ekm-metering-products/electric-meters-kwh-meters/smart-meters-read-meter-remotely-automatically.html?gclid=COKi1Jv6w7oCFcxaMgod4mIAsg>
 - Real-Time monitoring, <http://widget.ekmmetering.com/EKM2/?reads=100&key=MTAxMDoyMDIw&meter=10068>
 - Energy Auditing & Benchmarking, <http://www.ekmmetering.com/solutions/data-monitoring/energy-auditing-benchmarking.html>

Smart Meter Circuits, Block Diagrams

- TI Smart E-Meter: ARM/AMI, <http://www.ti.com/solution/docs/appsolution.tsp?appId=407>
- TI Application Notes
 - Implementation of a Single-Phase Electronics Watt-Hour Meter using MSP 430F6736 (Rev. B), Oct. 2013, <http://www.ti.com/lit/an/slaa517b/slaa517b.pdf>
 - Implementation of a three-phase electronic Watt-hour meter using the MSP430F677X (Rev. D), <http://www.ti.com/lit/an/slaa577d/slaa577d.pdf>



Maxim Smart Meters, <http://www.maximintegrated.com/solutions/guide/smart-grid/smart-meter.pdf>

- Silica_Metering_brochure_2011.pdf, www.maxim-integrated.com/Meter

FCI Smart Meter, Presentation, <http://www.ttiinc.com/docs/IO/24880/FCISmartMetersPresentation.pdf>

On Semiconductor Smart Grid Solutions, http://www.onsemi.com/pub_link/Collateral/BRD8075-D.PDF

Smart Grid Distribution and Smart Meter,

http://www.st.com/web/en/resource/sales_and_marketing/promotional_material/brochure/brmeter.pdf

Other References

Solar Energy Centers

- Florida, <http://www.fsec.ucf.edu/en/>

Net Energy Metering

- U.S. Dept of Energy (New York Net Metering Program) U.S. Energy.GOV, <http://energy.gov/savings/net-metering-26>
- New Mexico Solar Energy Association, http://www.nmsea.org/Education/General/Sites/Grid_Tied_Systems.php
 - New Mexico, http://www.nmsea.org/Education/Homeowners/NMSEA_PV_FAQ.pdf
- California, http://www.gosolarcalifornia.ca.gov/solar_basics/net_metering.php
- Case Study – One Sky, <http://www.onesky.ca/files/uploads/One%20Sky%20Net%20Metering%20Case%20Study.pdf>
- Pacific Power, <http://www.pacificpower.net/env/nmcg/nm/oregon/nmapm.html>
- Hawaii, <http://www.heco.com/heco/Clean-Energy/Clean-Energy-Generation/Net-Energy-Metering-in-Hawaii?cpsextcurrchannel=1>
- New York - DSIRE, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NY05R
- Vermont –DSIRE, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=VT02R
- **Evaluation of Net Metering in Vermont Conducted Pursuant to Act 125 of 2012**, Public Service Dept, Jan. 15, 2013, <http://www.leg.state.vt.us/reports/2013ExternalReports/285580.pdf>
- Florida Power & Light, http://www.fpl.com/residential/savings/net_metering/index.shtml
- Eugene, OR, <http://www.eweb.org/solar/netmetering>

Smart Meters and Net Metering

- San Diego Gas & Electric, <http://www.sdge.com/residential/about-smart-meters/smart-meters-and-net-metering>

Solar Energy Industries Association

- Net Metering, <http://www.seia.org/policy/distributed-solar/net-metering>
- Net Metering (Net Energy Metering) by State, <http://www.seia.org/research-resources/net-metering-state>

PV Magazine US: 99% of Installed PV systems in 2012 were net-metered projects, , <http://www.pv-magazine.com/news/details/beitrag/us--99-of-installed-pv-systems-in-2012-were-net-metered-projects-100010943/#axzz2jH2zC4oV>

Smart Grid Ready Solar Power Systems

- GE Ecomagination: Smart Grid Ready AC Residential Solar Electric System, by Charles S. Korman, Christian Wagner, and Neil Johnson, March 16-18, 2011, http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ns/eemtg032011_c11_smart_grid.pdf
- Module Embedded Microinverter Smart Grid Reday Residential Solar Eletric System, http://www1.eere.energy.gov/solar/pdfs/ge_summary.pdf

Off-Grid Solar Power

- Solar Power Systems for Remote Locations, (12, 24, or 48V DC), http://www.sunwize.com/index.cfm?page=business_highlights&crd=103
- SunWize Solar Electric Power Systems for Industry & Government, http://www.sunwize.com/index.cfm?page=business_items&crd=69

Grid-Tied (Ready) Solar Power

- Wholesale Solar, <http://www.wholesalesolar.com/complete-systems.html>
- Mouli Engineering, Inc., Four 230W Crystalline solar panels, 240V/20A wire, Sine wave inverter, <http://www.mysolarpod.com/?gclid=CLTc1dqawLoCFcxaMgodMhAA6g>

- Costco Grid-Ready Kits Online, <http://www.costco.com/CatalogSearch?storeId=10301&catalogId=10701&langId=-1&keyword=grape+solar>
 - 5170 watt, \$12,999.99
 - 3750 watt, \$11,299.99
 - 1250 watt, \$3,899.99
 - 500 watt, \$1,899.99
- Costco Off-Grid 400 Watt solar panel, \$1,399.99
- Grid-tied solar electric systems – Revision Energy, 2013/8, **Video**, <http://www.revisionenergy.com/maine-solar-power.php>
- Solar Works, http://solarwork.com/greatsolar_solarpvelectric.html
- Mr. Solar (Marine Solar, Grid Tie solar kit), <http://www.mrsolar.com/content/pre-packaged-systems.php>
- Grid Tie Inverters for Solar Electric Systems, Northern Arizona - Win & Sun, <http://www.solar-electric.com/gridtiesolar.html>
- Enphase micro-inverter
- 18 KW PV, <http://www2.buildinggreen.com/blogs/beating-achilles-heel-grid-tied-solar-electric-systems>
 - Sunny Boy 5000TL-US inverter, http://www.sma-america.com/en_US/products/grid-tied-inverters/sunny-boy/sunny-boy-3000tl-us-4000tl-us-5000tl-us.html

Commercial Solar Systems

- LG Solar, <http://www.lg.com/us/commercial/solar>
- Solar Power Solutions, <http://new.abb.com/solar>
- Siemens Smart Grid Solutions, http://w3.usa.siemens.com/smartgrid/us/en/Pages/smart-grid.aspx?stc=uszsg120124&sp_source=uszsg120124
- Solar Electric Power Systems, Schneider Electric, <http://products.schneider-electric.us/products-services/services/electrical-distribution-services/solar-electric-power-systems/>

Grid-Tied Solar Electric Systems, 2013/8/7, <http://www2.buildinggreen.com/blogs/beating-achilles-heel-grid-tied-solar-electric-systems>

Solar Power & Smart Grid Lab @ Votey, The University of Vermont, <http://www.uvm.edu/sustain/cef/cef-projects/solar-power-smart-grid-lab-votey>

Using Dynamic Pricing to Balance Solar Power with the Smart Grid, by Jeff St. John, 2013/8/20, <http://www.greentechmedia.com/articles/read/dynamic-pricing-to-balance-solar-power-with-the-smart-grid>

Solar Panles and the Smart Grid in the Pepco Region, 2009, 2009, http://www.solardecathlon.gov/past/pdfs/09_workshops/09_panels_grid.pdf

GE Plug-In to the Smart Grid – Ecomagination, <http://www.ge.com/about-us/ecomagination>

DOE Financial Opportunities, <http://www1.eere.energy.gov/financing/business.html>

Solar PV Basic

- Solar Photovoltaic Technology Basic, http://www.nrel.gov/learning/re_photovoltaics.html

- DOE Solar Energy Technologies, <http://energy.gov/eere/energybasics/articles/solar-energy-technologies>
- DOE Small Solar Electric System, July 15, 2012, <http://energy.gov/energysaver/articles/small-solar-electric-systems>
- PV for Small Business Owners, http://www.nrel.gov/learning/re_photovoltaics.html
- Solar Photovoltaic Technology Brief, International Renewable Energy Agency, January 2013, <http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E11%20Solar%20PV.pdf>

DOS EERE SunShot Initiative,

http://www1.eere.energy.gov/solar/sunshot/printable_versions/index.html

- Solar Energy Guide
 - Utility-Scale Solar Energy
 - Electric Transmission
 - Solar Energy Environmental Considerations
 - Photos
 - Links
 - EIA Solar Thermal Power Plants Web page, http://www.eia.gov/energyexplained/index.cfm?page=solar_thermal_power_plants
 - EIA Solar Thermal Collectors Web page, http://www.eia.gov/energyexplained/index.cfm?page=solar_thermal_collectors
 - EIA Solar Photovoltaic Web page, <http://www.eia.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html>
 - EIA Energy Kids Solar Web page
 - Bureau of Land Management – Solar Energy, <http://www.eia.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html>
 - International Solar Energy Society, <http://www.ises.org/index.html>
 - Solar Electric Power Association (SEPA), <http://www.solarelectricpower.org/>
 - America Solar Energy Society (ASES), <http://www.ases.org/>
 - The Solar Energy Industries Association (SEIA), <http://www.seia.org/>

European Photovoltaic Industry Association, <http://www.epia.org/about-us/about-photovoltaics/solar-photovoltaic-technology/>

IEA Technology Roadmap: Solar Photovoltaic Energy, May 11, 2010,

<http://www.iea.org/publications/freepublications/publication/name,3902,en.html>

PVTECH International, <http://www.pv-tech.org/>

- PV Taiwan 2013,

Solar Energy Development Programmatic EIS Information Center,

<http://solareis.anl.gov/guide/solar/pv/index.cfm>

Solar Energy (Distributed generation)

- Solar Photovoltaic (solar electric), <http://www.seia.org/policy/solar-technology/photovoltaic-solar-electric>

- Solar Thermal Power Plants (solar heating & cooling), <http://www.seia.org/policy/solar-technology/solar-heating-cooling>
- Solar Thermal Collectors (concentrated solar power), <http://www.seia.org/policy/solar-technology/concentrating-solar-power>
- Solar Energy & Environment
- Advantages vs. Disadvantages

Solar Power

- DC – AC conversion (Inverter)
- Utility scale
- Solar Industry Data, <http://www.seia.org/research-resources/solar-industry-data>

Solar Capacity

Solar Cost

Solar Deployment

Solar Products

Solar Panels, <http://www.solrwind.com/>

American Solar Energy Society, <http://www.ases.org/>

Solar Electric Power Association (SEPA), <http://www.solarelectricpower.org/welcome/solar-companies-.aspx>

Solar Energy Industries Association (SEIA), <http://www.seia.org/>

- 723 MW of solar PV were installed in Q1 2013

Solar Energy International, <http://www.solarenergy.org/>

EIA

- EIA Page on Renewable & Alternative Fuels, <http://www.eia.gov/renewable/>
- EIA Solar Photovoltaic Cell/Module Manufacturing Activities, <http://www.eia.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html>
- Short-Term Energy Outlook, http://www.eia.gov/forecasts/steo/report/renew_co2.cfm
 - Renewables and CO2 Emission
 - U.S. Electricity and Heat Generation from Renewables

U.S. Dept of Energy Solar Technologies Program,

<http://www1.eere.energy.gov/solar/sunshot/index.html>

- DOE SunShot Initiative
 - Photovoltaics
 - Concentrating Solar Power
 - System Integration
 - Soft Balance of Systems
 - High Penetration Solar Portal
 - SunShot Vision Study

GREEN JOBS (Careers in Solar Power) – U.S. Dept of Labor, Bureau of Labor Statistics,

http://www.bls.gov/green/solar_power/

- Scientific Research
- Solar Power Engineering

- Manufacturing for Solar Power
- Solar Power Plant Development
- Solar Power Plant Construction
- Solar Power Plant Operations
- Solar Photovoltaic Installers

Solar Buzz – Solar PV Industry Overview, <http://www.solarbuzz.com/>

Renewables - Solar Energy Statistics & Data

- California Solar Energy Statistics & Data, <http://energyalmanac.ca.gov/renewables/solar/>
 - Solar Thermal Electricity Production
 - Go Solar California Website (Info on Rebates and Incentives), <http://www.gosolarcalifornia.org/>
 - Solar PV Electricity, <http://energyalmanac.ca.gov/renewables/solar/pv.html>
 - Utility-Scale Solar Photovoltaic Projects, <http://www.energy.ca.gov/siting/solar/index.html#pv>
 - Solar Thermal Power Plants
 - Solar Hot Water Systems

BP Statistical Review of World Energy 2013, 48 pages,
http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf

2013 Energy in Charts – Energy Industry Statistics, by American Petroleum Institute,
<http://www.api.org/policy-and-issues/policy-items/american-energy/energy-in-charts>

NIPSCO Renewable Energy, <http://www.nipsco.com/en/green?gclid=CJ-q7vTtobkCFcU7MgodDHIABg>