Sensing & Measurement Research Activities through DOE's Grid Modernization Initiative

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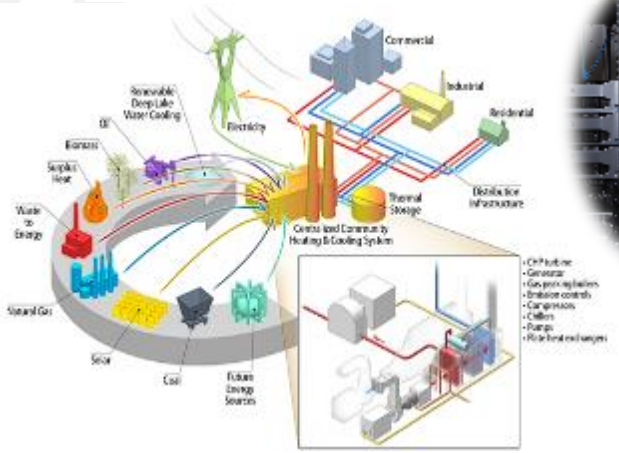
Sensing and Measurements

Objective: Sensor development and deployment strategies to provide complete grid system visibility for system resilience and predictive control

Expected Outcomes

- ► Advance and integrate novel, low-cost sensors to provide system visibility
- ► Develop real-time data management and data exchange frameworks that enable analytics to improve prediction and reduce uncertainty
- ► Develop next-generation sensors that are accurate through disturbances to enable closed-loop controls and improved system resilience



Federal Role

- ► Common approach across labs and industry test-beds for effective validation of emerging technologies
- ► Develop common interoperability and interconnection standards and test procedures for industry / vendor community

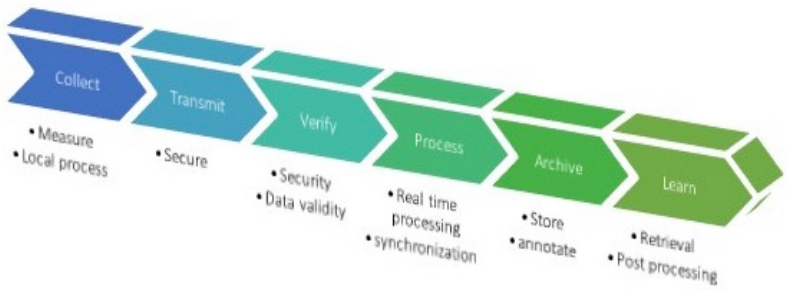
Grid Sensing & Measurement Activities & Technical Achievements

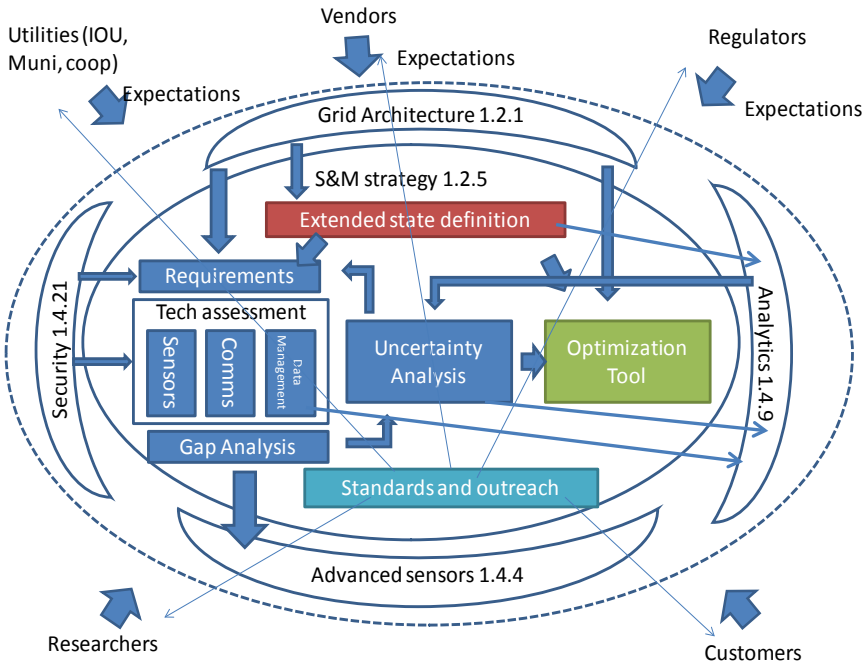
MYPP Activities	Technical Achievements by 2020
Improve Sensing for Buildings & End-users	Develop low cost sensors (under $10 per sensor) for enhanced controls of smart building loads and distributed energy resources to be "grid friendly" in provision of ancillary services such as regulation and spinning reserve while helping consumers understand benefits of energy options.
Enhance Sensing for Distribution System	Develop low cost sensors (under $100 per sensor) and ability to effectively deploy these technologies to operate in normal and off-normal operations Develop visualization techniques and tools for visibility strategy to help define sensor type, number, location, and data management. Optimize sensor allocation for up to 1,000 non-meter sensing points per feeder.
Enhance Sensing for the Bulk Power System: Develop Agile Prognostics and Diagnostics for Reliability & Asset Management	Develop advanced synchrophasor technology that is reliable during transient events as well as steady state measurement. Develop low cost sensors to monitor real-time condition of electric grid components. Using novel, innovative manufacturing concepts, develop low-cost sensors to monitor electric grid assets
Develop Data Analytic and Visualization Techniques	Provide real-time data management for the ultra-high velocities and volumes of grid data from T&D systems. Enable 100% visibility of generation, loads and system dynamics across the electric system through the development of visualization techniques and software tools Develop measurement and modeling techniques for estimating and forecasting renewable generation both for centralized and distributed generation for optimizing buildings, transmission, storage and distribution systems.
Demonstrate unified grid-communications network	Create a secure, scalable communication framework with a coherent IT-friendly architecture that serves as a backbone for information and data exchange between stakeholders and decision makers.

FY16 GMLC Projects

- Sensing & Measurement Strategy
- Advanced Sensor Development
  - End-use devices
  - Transmission & Distribution
  - Asset Monitoring
- Integrated Multi Scale Data Analytics and Machine Learning for the Grid

Project - Sensing & Measurement Strategy



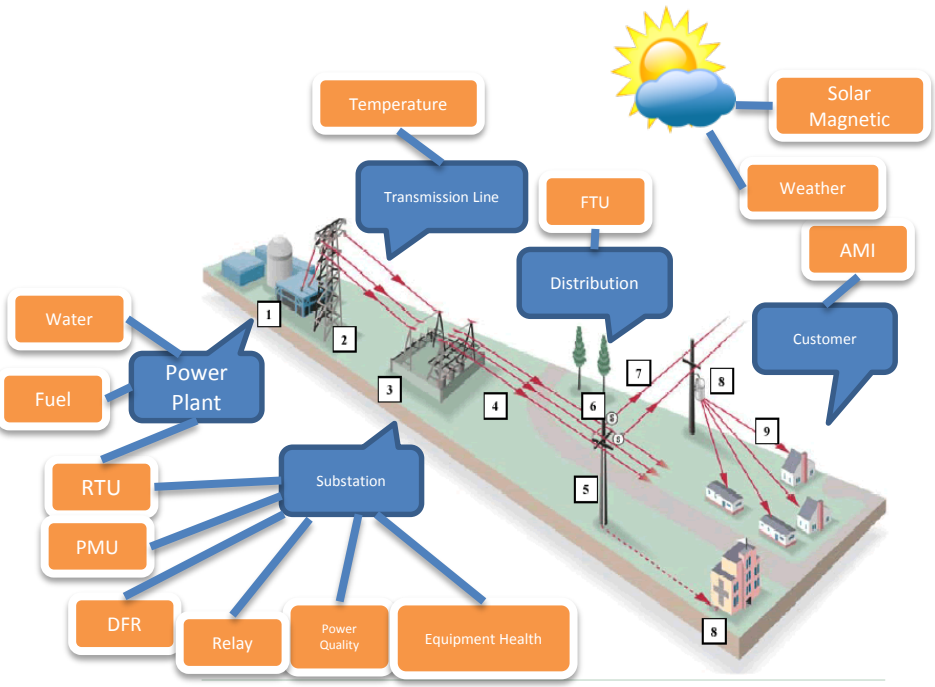


Identify measurement requirements along with associated data management and communication systems to achieve the MYPP goals. *Without an understanding of the true state of the system, these goals will never be realized.* This methodology includes: 1) defining the grid state, 2) developing a roadmap and 3) framework to determine sensor allocation for optimal results.

Labs: ORNL, PNNL, NETL, LLNL, ANL, NREL, SNL, LBNL, LANL

Partners: EPRI, Southern Co, EPB, Entergy, OSIsoft, Dominion, TVA, CommEd, NASPI

Project – Advanced Sensor Development



Modified from Duke Energy
https://www.progress-energy.com/florida/home/safety-information/storm-safety-tips/restoration.page?

Increase visibility throughout the energy system including transmission, distribution and end-use by developing low-cost, accurate sensors. Additionally, next generation asset monitoring devices will help determine state of grid components prior to failure.

Labs: ORNL, PNNL, NETL, NREL, SNL, LBNL

Partners: EPRI, University Tennessee, Southern Co, EPB, Entergy, Eaton, SmartSense, National Instruments, Dominion, TVA, ComEd, NASPI

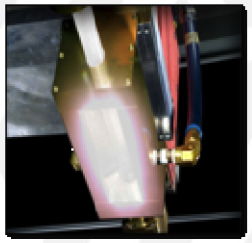
Low Cost Sensors & Controls – Technology Platform

Material Processing and Device Integration

Thin Film Deposition

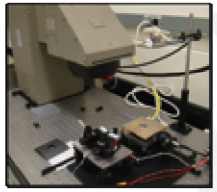
- Inkjet Printing
- Ultrasonic Spray
- Sputtering
- E-beam Evaporation

Low Temperature Photonic Curing



- PulseForge 3300
- Vortek-300
- Vortek-500

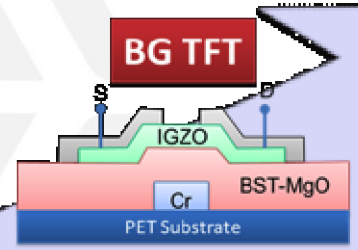
Materials and Device Characterization

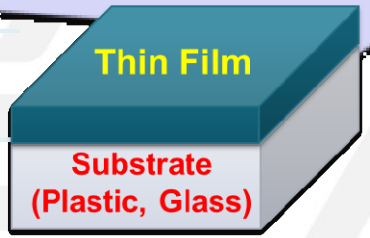


- CNMS
- CATS Lab
- NSTL
- EMC2
- RF-Clean Room
- RF Test Setups

TFT Development

- PTP Curing
- Multilayer Structure
- Characterization

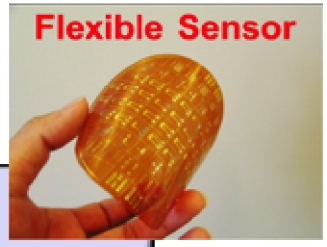




Plastic Integrated Thin Films

- Metal
- Semiconductor
- Dielectric

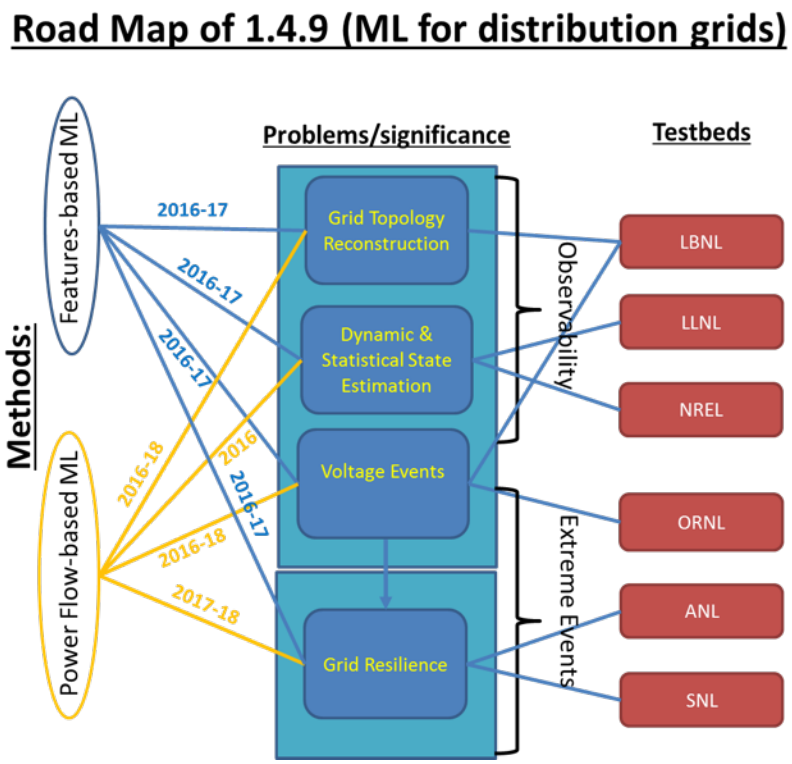
Development Target



Target Technologies

- **Sensors** (Electricity, Temperature, Environment, Mechanical)
- **Optoelectronics** (Phosphor, OLED, Display)
- **Batteries** (CNT, Nanoparticles, C-fiber)
- **RF Electronics** (Energy Harvesting, RF Tags)
- **Photovoltaics** (a-Si, CIGS, CZTS, Polymer)
- **Organic Electronics** (PV, Sensor, TFTs, RF)

Project – Distributed Analytics



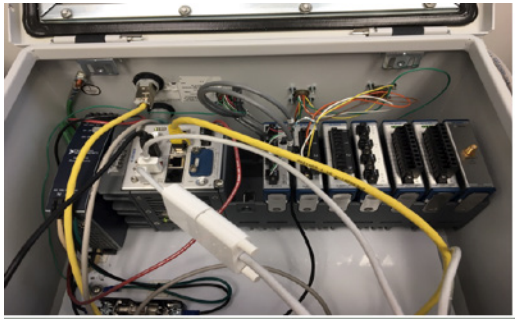
Developing a low cost scalable infrastructure for integrating disparate high fidelity data sources. Machine learning methodologies will be used to assist in transforming data into actionable intelligence. This platform will allow multiple entities to collaborate on data utilization.

Labs: LANL, SNL, LBNL, ORNL, LLNL, NREL, ANL

Partners: OSIsoft, National Instruments, PJM, EPB, Entergy, CommEd

Regional Project: Southeast Consortium

"Sensor Suite" for IoT monitoring



Step Distance Impedance Protection Using Optical Sensors

Establish a regional partnership that will increase utility clean energy portfolios and improve power system network resiliency to ensure increased reliability along with improved responsiveness under extreme conditions by eliminating outages or enabling faster restoration of power to critical loads

- Developed and Deploying Low Cost Sensor Suite
- Evaluated Time Sensitive Network within Utility
- Step Distance Impedance Protection Using Optical Sensors

Labs: ORNL, SRNL

Partners: University Tennessee, EPB, Southern Company, TVA, UNC-Charlotte, Duke Energy, Santee Cooper, Clemson

Connections and Collaborations

Foundational and Program Projects

13 Partnership Projects between National Labs – Industry – Universities

MYPP Area	Foundational Projects	Program-Specific Projects
Develop Low-cost advanced sensors	1.2.5 Sensing & Measurement Strategy 1.4.4 Advanced Sensor Project	GM0073 - HVDC and Load Modulation for Improved Dynamic Response using Phasor Measurements
Data Management & Analytics & Visualization	1.4.9 Distributed analytics	GM0070 - Discovery through Situational Awareness (DTSA) GM0072 - Suite of open-source applications and models for advanced synchrophasor analysis GM0077- Advanced Machine Learning for Synchrophasor Technology SI-1728 - Solar Resource Calibration, Measurement and Dissemination SI-1758 - Frequency Response Assessment and Improvement of Three Major North American Interconnections due to High Penetrations of Photovoltaic Generation WGRID-59 - WindView: An Open Platform for Wind Energy Forecast Visualization
Communications	1.2.5 Sensing & Measurement Strategy 1.3.5 SE Regional Project	SI-1586 - Opportunistic Hybrid Communications Systems for Distributed PV Coordination

Accomplishments and Emerging Opportunities

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U.S. Department of Energy

Accomplishment

- 1.2.5 Draft Extended Grid State framework and definitions incorporating industry feedback. Draft Technology Roadmap (including key use cases) with industry feedback submitted to DOE
- 1.4.4 End-use & Asset Monitoring sensor development has four invention disclosures & 2 patent applications; Developed algorithm for improved PMU under transient conditions;
- 1.4.9 Completed White Papers : What is machine learning and why do we need it from two perspectives building/grid and data science

Path Forward

- 1.2.5 Continue EGS and Roadmap efforts. Optimization Tool (SPOT Tool) development is underway; 1st application is a distribution state estimator
- 1.4.4 Evaluate performance of developed sensors; continue research on promising approaches;
- 1.4.9 Structure for testing and benefits assessment of the existing state of the art is identified and initial application will be demonstrated in early July

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Thank you

For More Information

http://energy.gov/under-secretary-science-and-energy/grid-modernization-initiative