Energy Systems Integration

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Today’s U.S. Energy System
What is Energy System Integration?

Energy system integration (ESI) = the process of optimizing energy systems across multiple pathways and scales.

Data Pathway: Information and communication technologies allow a better understanding and control of systems by linking sensor data from multiple locations to control centers.
Why Energy Systems Integration?

Existing energy systems have served us well... but a clean energy future needs a modernized and integrated infrastructure.
The Revolution is ... Coming Now
Today’s Electricity Grid

Generation  Delivery  Customer

Source: EPRI, 2009

NATIONAL RENEWABLE ENERGY LABORATORY
Tomorrow’s Power System

Source: EPRI, 2009
Future Energy System Architecture
An aggressive grid modernization strategy for the Department of Energy that includes

• Alignment of the existing base activities among the Offices
• An integrated Multi-Year Program Plan (MYPP)
• New activities to fill major gaps in existing base
• Development of a laboratory consortium with core scientific abilities and regional outreach
# Foundational R&D Areas

| Devices and Integrated Systems | • Establish common test procedures and interoperability standards for devices that can provide valuable grid services alone and/or in combination |
| Sensing and Measurements | • Visualization tools that enable complete visibility of generation, loads and grid dynamics across the electric system |
| System Operations and Power Flow | • Develop advanced real-time control technologies to enhance the reliability and asset utilization of T&D systems |
| Design and Planning Tools | • Create grid planning tools that integrate transmission and distribution and system dynamics over a variety of time and spatial scales |
| Security and Resilience | • Develop advanced security (cyber and physical) solutions and real-time incident response capabilities for emerging technologies and systems |
| Institutional Support | • Provide tools and data that enable more informed decisions and reduce risks on key issues that influence the future of the electric grid/power sector |
Grid Modernization Laboratory Consortium
Grid Integration Facility Network

INL
- SCADA / Cyber Test Bed
- Energy Systems Laboratory

NREL
- Energy Systems Integration Facility (ESIF)
- National Wind Technology Center (NWTC)

ANL
- Smart Grid Test Lab

PNNL
- EIOC
- NW Smart Grid

ORNL
- DECC

LBNL
- FlexLab

SDG&E
- ITF

SNL
- DETL
- SCADA Test Bed

Clemson
- 15 MW Grid simulator

FSU/CAPS
- 5 MW Grid simulator

SDG&E
- ITF

Planned

Connected
Energy Systems Integration Facility (ESIF)

Addressing the challenges of large-scale integration of clean energy technologies into the energy systems infrastructure

http://www.nrel.gov/esif

“This new facility will allow for an even stronger partnership with manufacturers, utilities and researchers to help integrate more clean, renewable energy into a smarter, more reliable and more resilient power grid.”

- Energy Secretary Ernest Moniz
“Smart Home” Example

Legend:
- **Power**
- **Comm**
- **System Data**
- **Experiment Data**

- **GridLab-D Dist sim**
- **Experiment DAS**
- **HPC / DC**
- **Grid Sim**
- **Market Simulator**
- **Market**
- **Home EMS**
- **System Control**
- **Local Control**
- **Device: Fridge**
- **Device: Water Heater**
- **Device: PV Inverter**
- **Device: EV**
- **Communications, Information, and Computation**

Local Electrical connection in SPL - 240V, 1ph
ESIF Smart Power Lab

Hardwired PV

Home EMS

EV, EVSEs, & battery storage

Distribution Transformers

Thermal Energy Storage

Major Appliances

Hot Water use under simulated occupancy

Environmental Chambers for realistic HVAC loading

Hot Water use under simulated occupancy
Grid Integration Capabilities at ESIF

- Rooftop PV & Wind
- Energy Storage Lab: Residential, Community & Grid Battery Storage, Flywheels & Thermal
- Smart Power Lab: Buildings & Loads
- HPC & Data Center
- Energy Systems Integration Lab: Fuel Cells, Electrolyzers
- Power Systems Integration Lab: Grid Simulators, Microgrids
- Outdoor Test Areas: EVs, Power Transformers
- Auxiliary Control Room: ADMS Testbed
Grid Integration Capabilities at NWTC

2020 Goal: Establish ~10 MW scale integration capability at NWTC
Modeling and Simulation at ESIF

Commissioned September 2013
1.2 PFlop peak performance
World-leading PUE < 1.06

Network graph from TDS hub
A Design Process for Clean Energy

Hardware Testing
- PV Simulator
- Devices Under Test (e.g. inverter, energy storage, EV, loads)
- Load Banks
- Grid Simulator

Modeling & Simulation
- Utility Substation
- Subdivision with PV at end of circuit

Field Deployment

Continuous Learning and Improvement
Our Vision

Reliable, affordable and clean energy systems adopted at a pace and scale to meet global energy and environmental objectives.
A Global Effort

Vision
A global community of scholars and practitioners from leading institutes engaged in efforts to enable highly integrated, flexible, clean, and efficient energy systems

Objectives
• Share ESI knowledge and Experience
• Coordination of R&D activities
• Education and Training Resources

Recent Activities
• Sept ‘14 Meeting w/IEA at NREL, USA
• Mar ‘15 Workshop Imperial College UK
• Energy Systems 101 KU Leuven Belgium
For More Information

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Energy Systems Integration
Accelerating the Clean Energy Future