Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

GridLAB-D

2010 Peer Review

GridLAB-D

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Overview

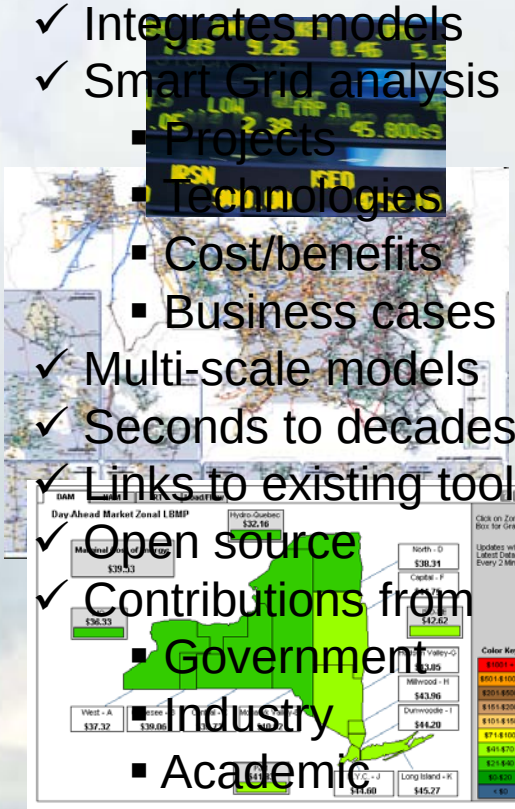
- What is GridLAB-D?
- Why use GridLAB-D?
- How does GridLAB-D work?
- How has GridLAB-D been used so far?
- What is it expected in the coming year?
- Funding and management details

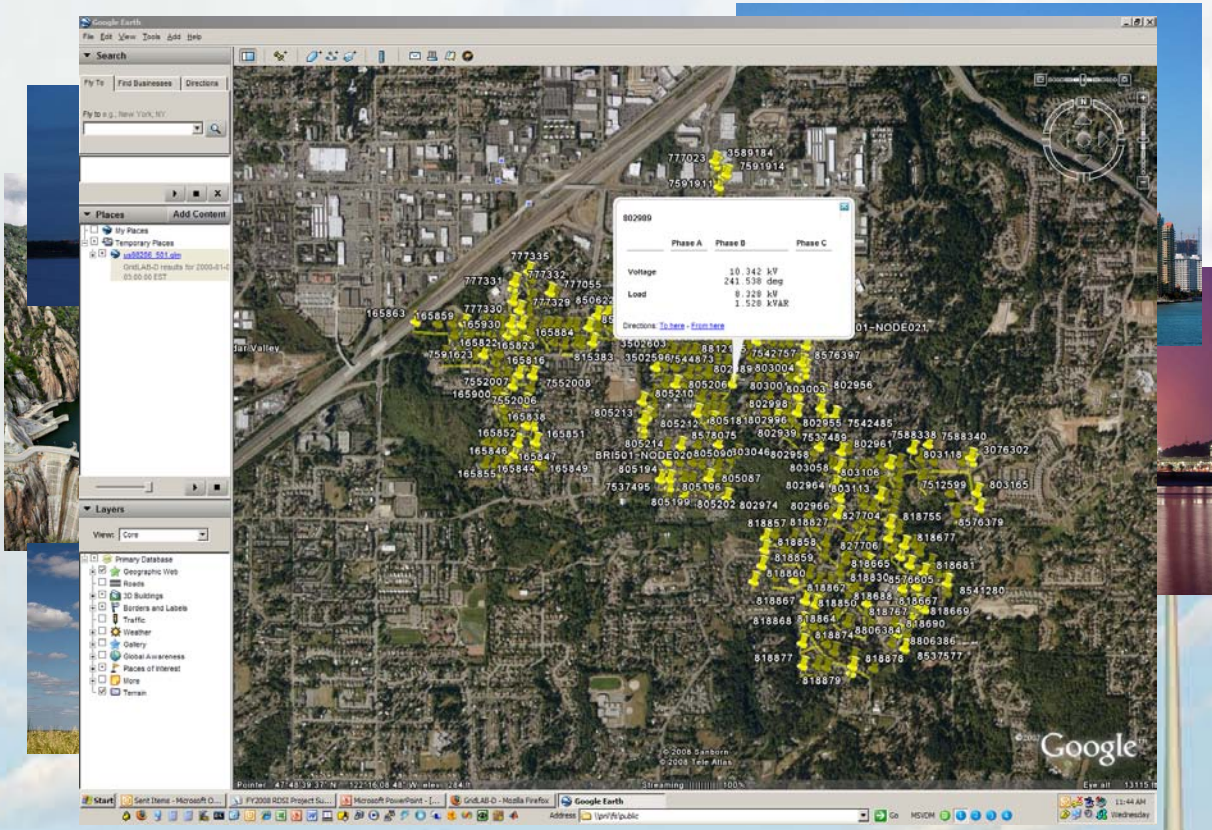
GridLAB-D Simulates the Smart Grid

- ✓ Next generation tool
- ✓ Integrates models
- ✓ Smart Grid analysis
  - Projects
  - Technologies
  - Cost/benefits
  - Business cases
- ✓ Multi-scale models
- ✓ Seconds to decades
- ✓ Links to existing tools
- ✓ Open source
- ✓ Contributions from
  - Government
  - Industry
  - Academic
  - Vendors

GridLAB-D models unifies keys elements of a Smart Grid

Market models | Power system models | Load models





- ✓ Drives need for high performance computers
- ✓ Vendors can add/extract modules for their own uses

Why simulate the smart grid?

- ✓**Evaluate the potential** of new technologies & operational strategies to save capital costs, improve reliability, & provide benefits like ancillary services
- ✓**Craft and refine** the characteristics of technologies and operational strategies to provide maximum benefit at the lowest cost
- ✓**Understand and quantify the synergies** among smart grid technologies
- ✓**Avoid unintended consequences** from utilizing distributed control strategies
- ✓**Predict, evaluate, & extrapolate** deployment project results

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How does GridLAB-D work?

- **Simultaneous solution** of loads and load flow
  - quasi-steady state, ~1-sec to 1-hr time steps
  - prototypical example: conservation voltage reduction
- **Time-series** simulation of distribution systems operations and expansion
  - off-line, not operations
  - technology planning & evaluation, not distribution engineering
  - but … open-source modules can be used in commercial products
- Detailed, simultaneous simulation of **power flow, end use loads,** and **market** functions and interactions (including weather and regulatory)
- Time scales from **seconds to decades** (time steps variable, user defined)
- Software consists of a **system core,** which loads and synchronizes **'plug-in' modules**, which deliver modeling functionality
  - modules are independently produced, compiled, and distributed
  - core manages input, time steps, variable sharing, convergence, and output

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How has GridLAB-D Been Used?

Goal: Analyze the benefits of GE's Coordinated/Integrated Volt-VAR control as deployed on the AEP distribution system

- Calibrated simulation of expected benefits
- Evaluate field data for GE technology
- Compare expected & actual results
- Explain nature of savings effects
- Extrapolate benefits to AEP footprint

Client: American Electric Power (AEP)

Team: Kevin Schneider (PI), Jason Fuller, Frank Tuffner, Yousu Chen, and Ruchi Singh

Goal: Build the full-value business case for scalable demand response (DR) networks

- Simulate traditional DR programs & PNNL's RTP/transactive control
- Evaluate benefits for generation, transmission, & distribution avoided costs, wholesale & carbon benefits
- Compare DR with & without efficiency

Client: CRN (NRECA), CoServ/Brazos Coops, TVA/Caney Fork Coop

Team: Rob Pratt (PI), Jason Fuller, Kevin Schneider, Tom Secrest, David Chassin

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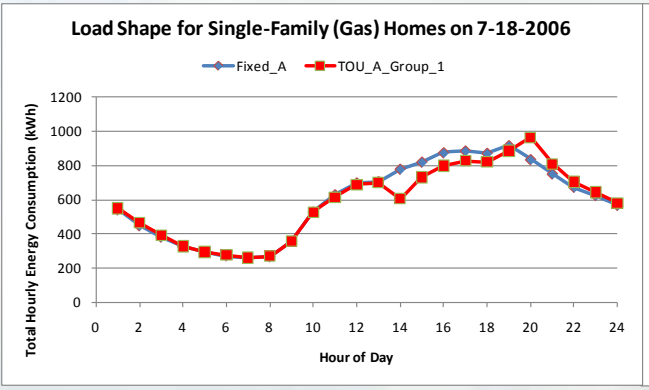
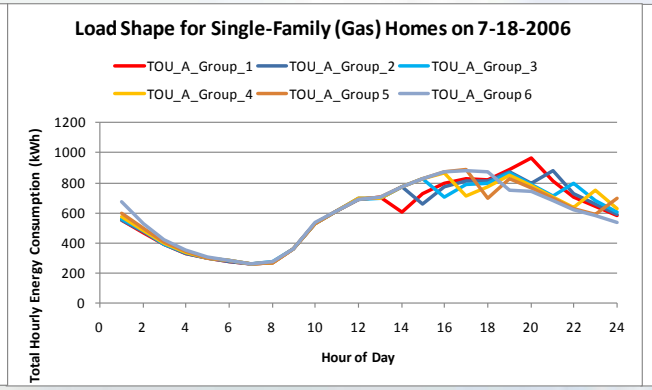
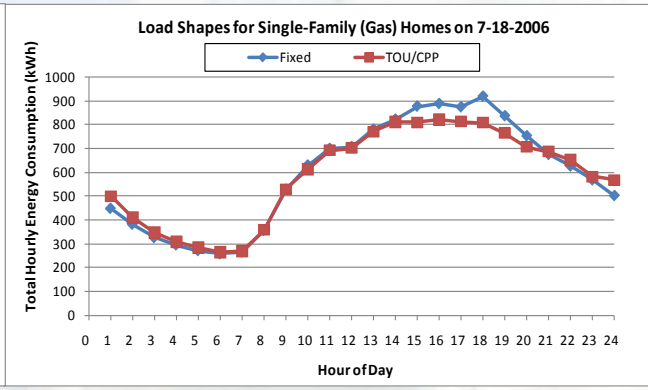
Key Findings and Strategic Importance



Traditional CPP Program – "rebound" sets new peak!

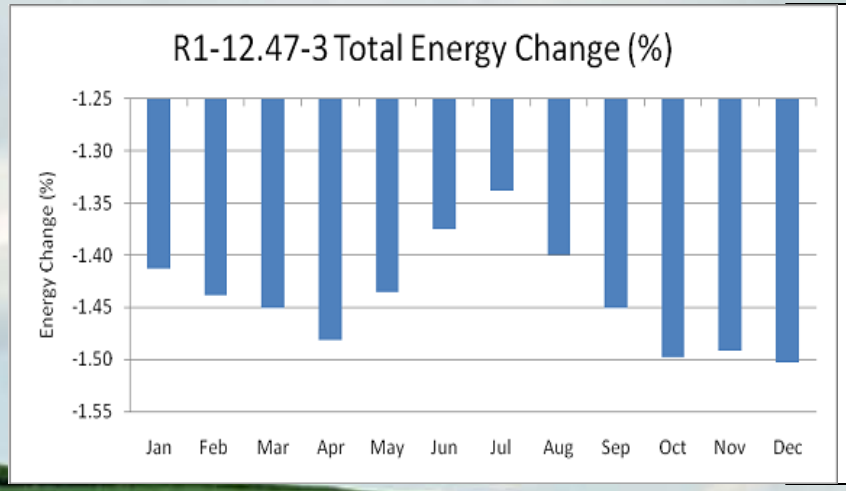


Staggered CPP Pricing



Reduces Peak Distribution Capacity Requirement by 11.5%

K. Schneider, National CVR Benefit Analysis Report, PNNL Report 19596, 2010.



- Strong seasonal variations in the effectiveness of volt-VAR control (VVC) were identified
- Examination of multiple substations showed VVC is well suited to some (not all) feeder types
- Detailed modeling shows energy savings were primarily in load reduction, not loss reduction
- Impossible to study problem without **combined** powerflow and voltage responsive load.

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How is GridLAB-D Being Used

- Commercial projects
  - Major international business IT vendor creating a user interface to commercialize tools based on GridLAB-D
  - GE CRADA to study smart appliance control strategies
  - PNM modeling of Albuquerque/Mesa del Sol (UNM)
  - AEP Smart Grid demo
- Academic
  - Renewable integration (UVic/BC Hydro)
  - Distribution analysis course taught at University of Washington
  - Invited lectures: MIT/Harvard/BU, UNM, UNCC, UVic, DTU
- Others (4000+ downloads in 2010)
- ARRA Projects
  - 4 separate analysis efforts of SGIG projects

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SGIG Analysis Methodology

- ~100 SGIG project → representative sample will be analyzed
- Select technologies that dominate impact of Smart Grid
- Apply to the 24 Modern Grid prototypical feeders.
- Extrapolate SGIG impacts to estimate national potential
- The selected technologies are:
  - Conservation Voltage Reduction
  - Demand Response
  - Energy Storage/PHEVs
  - Distribution Automation
  - Renewables Integration

GridLAB-D Commercialization

- Open source distribution using SourceForge
  - Access to source code by all
  - Updates monitored/controlled by PNNL staff
  - Extensive online documentation and course materials
  - Examples and reference models
  - Q&A forums, issue tracking, analytics
- Open source licensing
  - Vendors can add/replace components freely
  - Extract components for commercial use
  - No restrictions on use/application
  - Sell add-on modules but keep them proprietary

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GridLAB-D History

- FY07 – Prototyping ($587k)
  - Technology demonstration
  - Requirements development
- FY08 – Development ($750k)
  - Core implementation
  - Prototype module implementations
- FY09 – Validation ($700k)
  - Main module implementations
  - Model validation
- FY10 – Preliminary analysis ($1M)
  - Rate designs
  - Conservation voltage reduction
  - Model extensions for expected future studies

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GridLAB-D FY 11 Plan

- Budget is $1.3M
- Two main activities at PNNL
  - Analysis of SGIG projects
    - 4 separate technology portfolios
    - Report on impacts assessment due Sept 2011
  - Technical support
    - Outreach (classes, papers, conferences)
    - Technical support for other projects
    - Module enhancements for SGIG
    - Build/release activities (version 2.2)

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Questions

Contact david.chassin@pnl.gov

Online at http://www.gridlabd.org/

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GridLAB-D Capabilities

- Data processing
  - Input (weather, prices, consumer behaviors)
  - Output (recordings, histograms, aggregates)
- Powerflow
  - All common distribution components
  - Most common transmission components
- Load models
  - Residential (w/appliances)
  - Commercial (small office)
  - Appliances (FY11 MtTech)
- Controls
  - Transactive control (FY11 PNNL)
- Markets/pricing
  - Retail (multiple rates)
  - Wholesale (FY11 ISU)
- Reliability
  - IEEE 1366 metrics
- Communications
  - Behavior (FY11 PNNL)
- GUI API
  - Web-based (FY11 Battelle)
- High-performance computing
  - Core (FY11 UNM)
  - Modules (FY11 Battelle)

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Select Papers and Conferences

- **GridLAB-D: An open-source power systems modeling and simulation environment**
  Chassin, D.P.; Schneider, K.; Gerkensmeyer, C.; Transmission and Distribution Conference and Exposition, 2008. T&D. IEEE/PES Digital Object Identifier: 10.1109/TDC.2008.4517260 Publication Year: 2008 , Page(s): 1 - 5
- **Accelerating the Gauss-Seidel Power Flow Solver on a High Performance Reconfigurable**
  Computer Jong-Ho Byun; Ravindran, A.; Mukherjee, A.; Joshi, B.; Chassin, D.; Field Programmable Custom Computing Machines, 2009. FCCM '09. 17th IEEE Symposium on Digital Object Identifier: 10.1109/FCCM.2009.23 Publication Year: 2009 , Page(s): 227 - 230
- **Simulating demand participation in market operations**
  Chassin, D.P.; Widergren, S.E.; Power & Energy Society General Meeting, 2009. PES '09. IEEE Digital Object Identifier: 10.1109/PES.2009.5275369 Publication Year: 2009 , Page(s): 1 - 5
- **Distribution power flow for smart grid technologies**
  Schneider, K.P.; Chassin, D.; Chen, Y.; Fuller, J.C.; Power Systems Conference and Exposition, 2009. PSCE '09. IEEE/PES Digital Object Identifier: 10.1109/PSCE.2009.4840078 Publication Year: 2009 , Page(s): 1 - 7
- **Integrated retail and wholesale power system operation with smart-grid functionality**
  Aliprantis, Dionysios; Penick, Scott; Tesfatsion, Leigh; Huan Zhao; Power and Energy Society General Meeting, 2010 IEEE Digital Object Identifier: 10.1109/PES.2010.5589594 Publication Year: 2010 , Page(s): 1 - 8