2012 Smart Grid R&D Program Peer Review Meeting

GridLAB-D Analysis of Smart Grids

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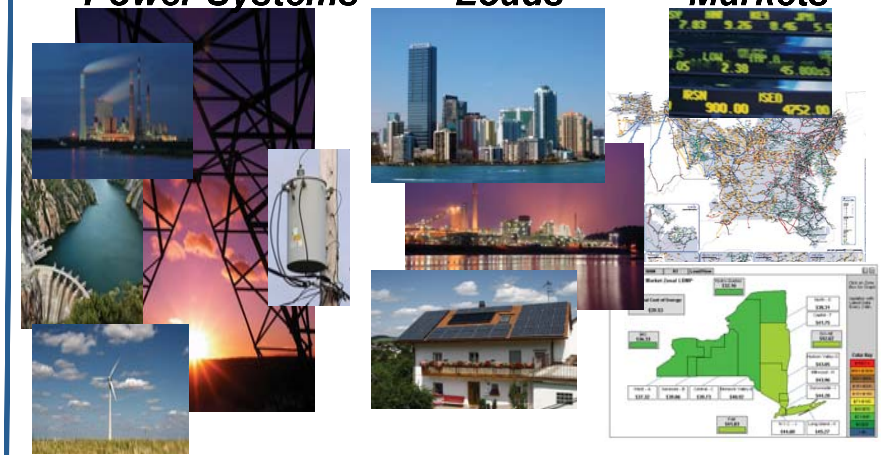
GridLAB-D Analysis of Smart Grids

Objective

Use GridLAB-D to quantify the impact of smart grid technologies, such as microgrids, distributed renewables, and new advanced load control strategies. GridLAB-D can simulation these different technologies in an accelerated time-frame to help assess their value and enhance their benefits.

Power Systems ***Loads*** ***Markets***



Life-cycle Funding Summary ($K)

Prior to FY12	FY12 authorized	FY13 requested	*Out-year(s)
$4,500	$1,425	$1,330	
GridLAB-D Base		$400	$400/yr
NRECA		$150	
Micro-Grid Controls		$240	
Camp Smith Modeling		$240	
Integrated T&D Control		$300	
*Out-year(s) funding does not include new starts beyond FY13.			

Technical Scope

Combine quasi-steady and dynamic models of power network and equipment, building and end-use loads, control systems, power markets, telecommunications into an agent-based tool that can simulate smart grid system behavior from sub-second to years. The data collected from these simulations is used to evaluate the impacts of new technologies, controls strategies, and business models of smart grid technologies.

Significance and Impact

GridLAB-D is a DOE/OE-funded open-source analytic tool the helps DOE drive utilities, policy-makers, and regulators to champion and use smart grid technologies that make the US more secure and globally competitive.

GridLAB-D is a transformational tool in the study of smart grid technologies

1. GridLAB-D users develop strategies for cost-effective, reliable, and efficient energy production, delivery and use.

2. Vendors and utilities base business cases for products and services on GridLAB-D results.

3. GridLAB-D drives the development and adoption of technologies that are key to modernizing US electricity delivery infrastructure and build demand for US-developed smart grid technology world-wide.

Significance and Impact

GridLAB-D provides a comprehensive environment to design, test, and optimize smart grid technologies before they are deployed in the field.

Allows smart grid technology developers to test

- **Distribution automation** – DA technologies can be evaluated and tested extensively before they are field in costly trials and demos.
- **Microgrids** – Test device controls and efficiency in integrated systems.
- **Communications, command and control systems** – Tests requirements for and benefits of increased communications performance.
- **Consumer impacts and effect of consumer behavior** – Examine both the impact of and the impact on consumers.
- **Business cases** – Provide utilities with economic cost/benefit analysis.

Technical Approach & Transformational R&D (Multi-objective Controls)

1. Grid modernization requires significant capital investments with often competing business objectives supported by a single investment.
2. Operational systems are often required to reconcile multiple objectives.
3. A framework is being developed for utilities to implement multi-objective controls to accelerate return on investments in DER/DR/PV/PEV

Initial focus in FY12 is on several distinct dual-objective controls strategies

1. Demand response services: peak shaving vs. ramping services
2. Energy storage services: peak shaving vs. voltage regulation
3. PHEV services: peak shaving vs. ramping services.

Technical Approach & Transformational R&D (Microgrids)

1. Increase system reliability by reducing local dependence on bulk system
2. Study smart grid controls and impacts in a small, self-contained environment.
3. Allow testing of key smart + efficient concepts such as combined heating/cooling/power.

Use GridLAB-D to study microgrid technologies impacts and application benefits

1. Model moderate-sized microgrids
2. Test multi-objective controls
3. Evaluate performance and reliability

Technical Approach & Transformational R&D (Integrated T&D Modeling)

Aggregate SG asset modeling – *What are smart grid resources doing*?

1. Develop reduced-order models of all major controllable smart grid assets
2. Special attention given to integrating reduced-order models of distribution assets
3. Validate models using detailed simulations and end-use metering data

Resource control design – *What can we tell the resources to do*?

1. Test and validate existing control DR control strategies like DLC and RTP
2. Design closed-loop DR control strategies, GFA, DR for wind/PV following, etc.

Measurement system modeling – *Can we see what resources are doing*?

1. Validate models & strategies using sub-hourly metering & market data from demo projects

Technical Accomplishments (Prior years)

1. **Tool development** – Development of the simulation technology that makes GridLAB-D the most flexible and powerful smart grid analysis tool available.

2. **NRECA study** – This study examined the business case for Smart Grid technologies for rural electric cooperatives.

3. **AEP Demo** – Provided detailed simulations in support of the successful RTP rate-case presented to PUCO.

4. **GE CRADA** – Examined the impacts of various smart appliance control strategies for appliance manufacturers, consumers and utilities.

5. **SGIG Analysis** – Examined the performance impact of the SGIG technologies in four principal areas (**distribution automation**, **demand response**, **renewable integration**, and **energy storage**)

Technical Accomplishments (FY 12)

1. **Multi-objective controls** for smart grid distribution technologies.
2. **Dynamic models** for microgrid studies.
3. **Integration with transmission simulation** to study of integrated T&D controls for applying smart distribution system technologies
4. **Technical support and training** also provided for
    1. Training program for smart grid engineering (DOE)
    2. Maui Smart Grid demonstration project (DOE)
    3. Fault-induced delayed voltage recovery (DOE, WECC/LMTF)
    4. Smart grid communications system analysis (LDRD)
    5. Courses taught/scheduled: AEP, SDG&E, NRECA, UCB/LBNL, Stanford

        Requested/planned: SNL, Santa Fe Institute, UNM, LANL

Technical Accomplishments (Planned)

1. **Advanced distribution controls using integrated T&D models**

   FY13 – Test bulk system models using aggregate load control and monitoring
   FY14 – Synthesize aggregate smart grid control function for operations

2. **Smart Grid analysis**

   FY13 – Evaluation demonstration project technologies (NRECA)
   FY13 – Microgrid modeling and controls (ORNL and others)
   FY13 – Modeling of DOD installations (PACOM)

1. **User interface for existing study models**

   FY13 – Deploy user interfaces for existing analyses
   FY14 – Deploy DMS/EMS interface for real-time smart grid testing/training

2. **Technical support, outreach and education of fast growing user base**

   FY13 – Continue growth and support of user base
   FY13 – GridLAB-D Association launch by charter members identified in FY12

Project Team Capabilities & Funding Leverage (Selected GridLAB-D Users/Collaborators)

1. **General Electric** – Testing an IVVC control strategy for AEP Ohio
2. **General Electric** – Studied advanced smart appliance control strategies
3. **AusGrid** – Integrated GridLAB-D with DMS to test new control strategies
4. **Lawrence Livermore National Lab** – HPC use for Smart Grid program
5. **National Renewable Energy Lab** – Integrated NREL's photovoltaic models
6. **University of Victoria** – Studied wind integration for BC Hydro
7. **Stanford University** – GridLAB-D integrated with GridSpice in a new commercial venture.
8. **QADO** – Using GridLAB-D to help New Jersey address transmission constraints using demand response

Project Team Capabilities & Funding Leverage (DOE Role)

1. **DOE provides leadership and vision of applications and studies.**
    1. PNNL provides key technical resources for DOE's vision.
2. **DOE leveraging industry efforts to develop new technologies that support Smart Grid vision.**
    1. GridLAB-D is the leading tool for evaluation cost/benefits and business cases.
3. **DOE funding supports industry attempts to understand and apply Smart Grid technology rapidly and reliably.** Examples:
    1. GE CRADA – tested appliance control strategies *in silico* to make business case for smart appliance technology.
    2. AusGrid – tested IVVC strategy with DMS to validate both system and usability for operators.

Contact Information

<u>Principle Investigator</u>

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Back-up Slides

Include any back-up slides you would like to provide to the peer reviewers and DOE program managers for additional information. The back-up slides will not be shared with others, unless specifically stated by the presenter.

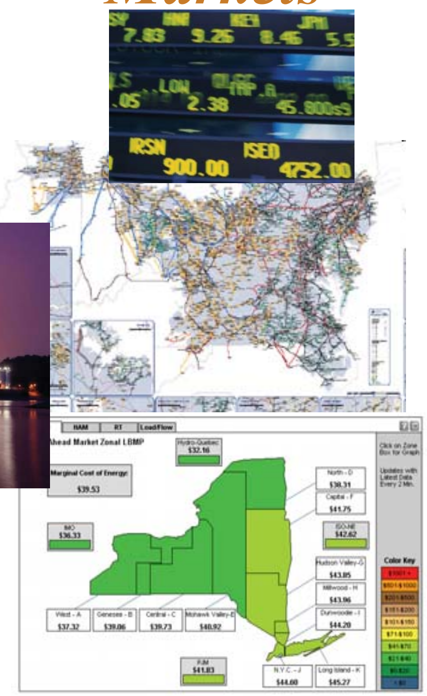
A Unique Tool for Designing and Studying Smart Grids

Unifies models of the key elements of a smart grid

Power Systems

Loads

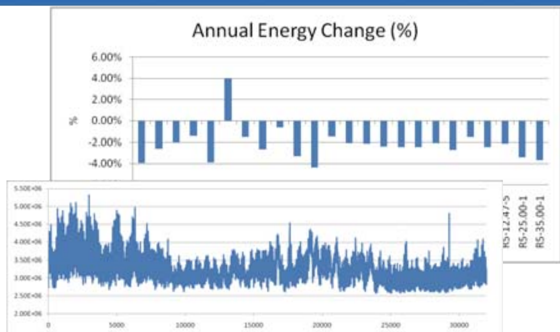
Markets



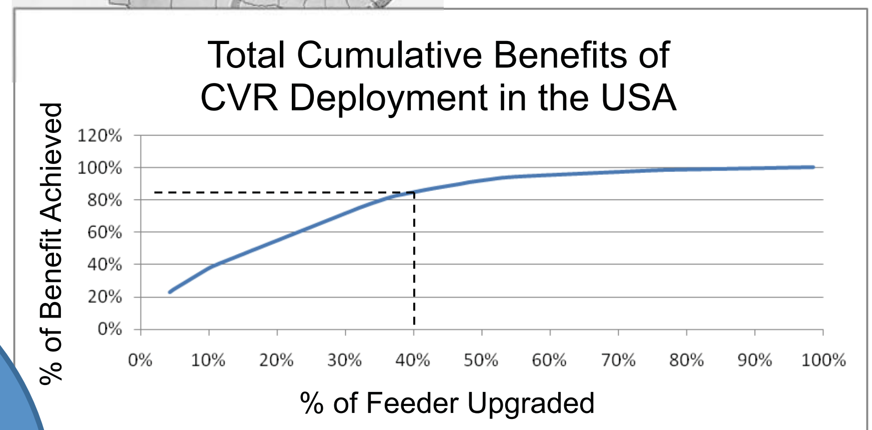
- ✓ Smart grid analyses
  - field projects
  - technologies
  - control strategies
  - cost/benefits
- ✓ Time scale: sec. to years
- ✓ Open source
- ✓ Contributions from
  - government
  - industry
  - academia
- ✓ Vendors can add or extract own modules

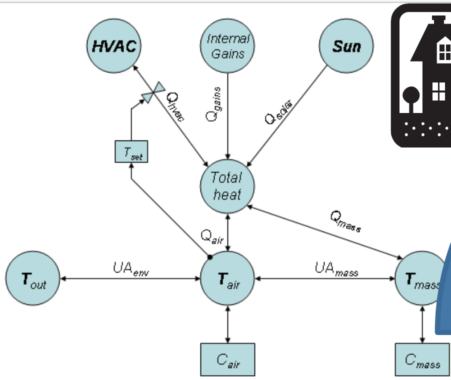
- ➢ GridLAB-D is a DOE-funded, open–source, time-series simulation of all aspects of operating a smart grid from the substation level down to loads in unprecedented detail
- ➢ Simultaneously solves:
  - ■ Unbalanced, 3-phase power flow (radial or network), w/explicit control strategies
  - ■ End use load physics, voltage-dependency, behavior & control in 1000s of buildings.
  - ■ Double-auction retail supply/demand markets

National Conservation Voltage Reduction Study



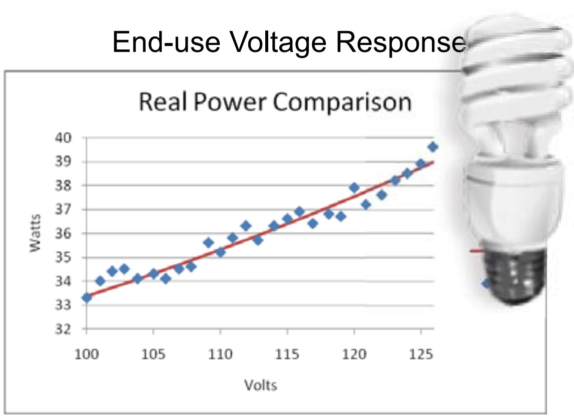
Region	Feeder	kV	# of feeders	% within a region
Region 1	R1-12.47-1	12.5	2,200	20.56%
	R1-12.47-2	12.47	2,500	23.36%
	R1-12.47-3	12.47	2,000	18.69%
	R1-12.47-4	12.47	1,800	16.82%
	R1-25.00-1	24.9	1,200	11.21%
	GC-12.47-1	12.47	1,000	9.35%
Region 2	R2-12.47-1	12.47	3,500	18.72%
	R2-12.47-2	12.47	3,200	17.11%
	R2-12.47-3	12.47	3,000	16.04%
	R2-25.00-1	24.9	3,500	18.72%
	R2-35.00-1	34.5	4,000	21.39%
	GC-12.47-1	12.47	1,500	8.02%
Region 3	R3-12.47-1	12.47	1,500	30.00%
	R3-12.47-2	12.47	1,500	30.00%
	R3-12.47-3	12.47	1,000	20.00%
	GC-12.47-1	12.47	1,000	20.00%
Region 4	R4-12.47-1	13.8	14,000	33.14%
	R4-12.47-2	12.5	15,000	35.50%
	R4-25.00-1	24.9	12,500	29.59%
	GC-12.47-1	12.47	750	1.78%
Region [illegible]	R5-12.47-1	13.8	400	8.79%
	R5-12.47-2	12.47	600	13.19%
	R5-12.47-3	13.8	650	14.29%
	[illegible]	12.47	[illegible]	10.99%
	[illegible]2.47-5	12.47	450	[illegible]
	R5-25.00-1	22.9	450	[illegible]
	R5-35.00-1	34.5	500	[illegible]
	GC-12.47-1	12.47	1,000	[illegible]





GridLAB-D
25 feeders x 1 minute over 1 year x 2 cases

End-use Voltage Response

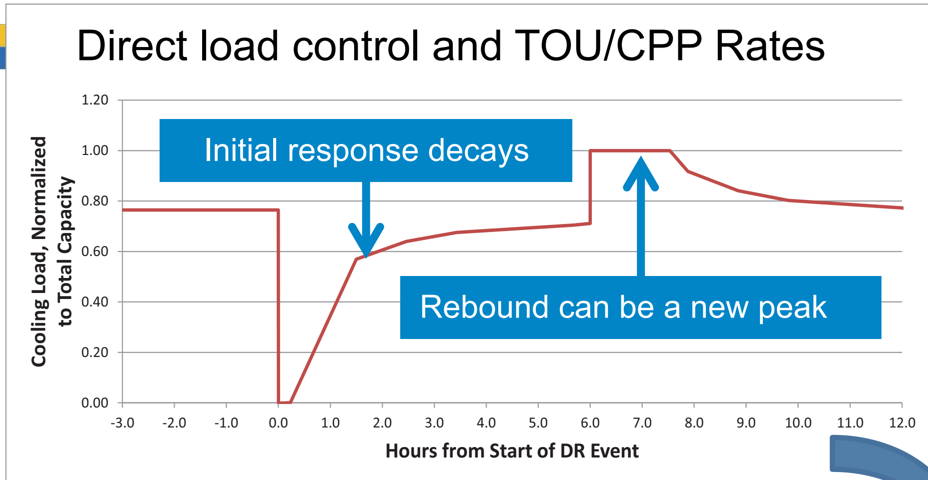


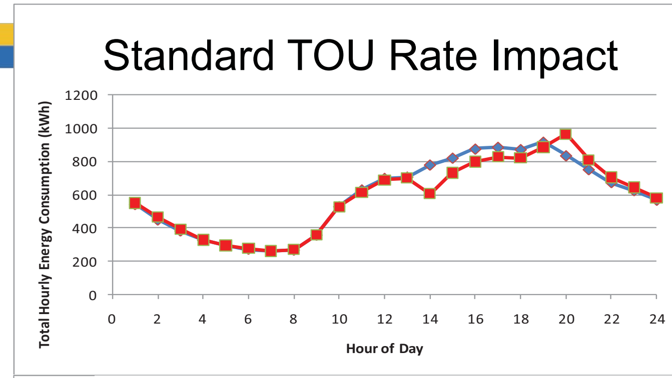
Keys Results:

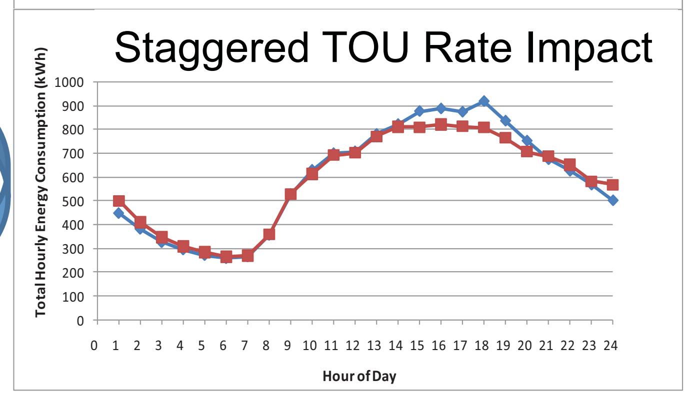
1. **Peak load reductions between 0.5% and 3%**
2. **Benefits vary widely depending on feeder, etc.**
3. **100% deployment saves ~3% national energy**
4. **40% deployment saves ~2.4% national energy**

Ref: **Evaluation of Conservation Voltage Reduction on a National Level**
Schneider, K.P., Fuller, J.C., Tuffner, F., Singh, R.
Pacific Northwest National Laboratory report for the US Department of Energy, 2010

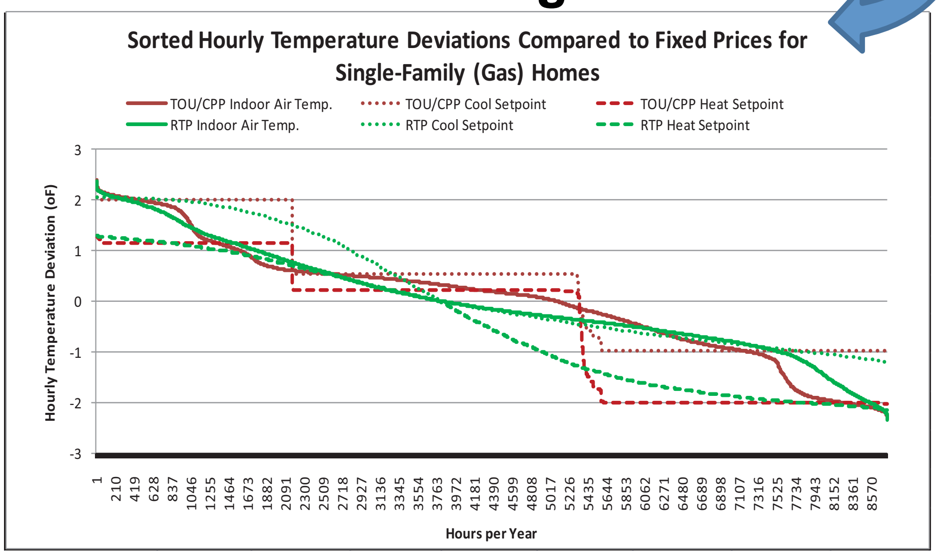
Demand Response Business Case Study







GridLAB-D: Calibrated residential & Commercial building load models



Key results:

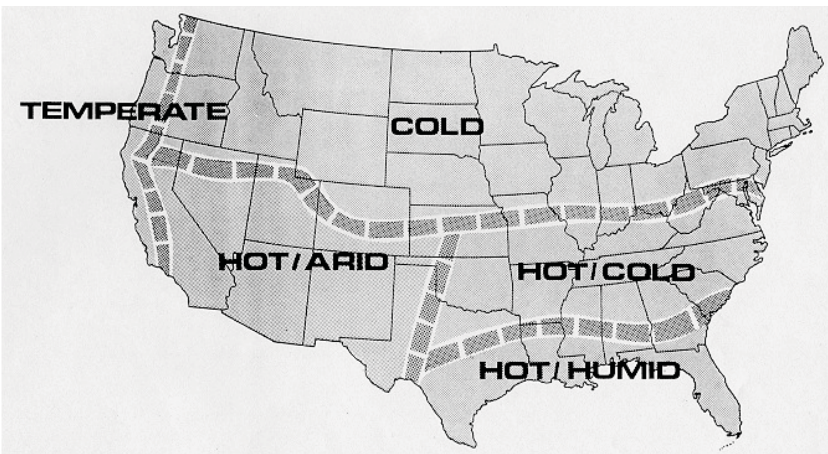
1. Single family homes offer most returns (16% reduction)
2. New construction less costly
3. All competitive with coal
4. Existing commercial not competitive with CT
5. Comfort/billing impacts minimal

Potential Impacts of SGIG Technologies

- **Distribution automation benefits**
  - Volt-VAR optimization (annual energy saved) — 2% – 4%
  - Reclosers & sectionalizers (SAIDI improved) — 2% – 70%
  - Distribution & outage management systems (SAIDI improved) — 7% – 17%
  - Fault detection, identification, & restoration (SAIDI improved) — 21% – 77%
- **Demand response**
  - Instantaneous load reductions — 25% – 50%
  - Sustainable (e.g., 6-hour) load reductions — 15% – 20%
- **Thermal storage (commercial buildings)**
  - Peak load reduction @ 10% penetration: up to 5%
- **Residential photovoltaic generation** (3 kW- 5 kW each)
  - 0% – 6% penetration (annual energy saved): 0.1% – 3%
  - Low penetration: losses generally decreased
  - High penetrations, uncoordinated deployment: can increase system losses

Simulation Models for National Scale Analysis

- **Annual simulations of Taxonomy Feeders**



- 25 feeder models
- One-minute time-steps
- Regionalized to extrapolate national level impacts

- **Technologies individually compared with base case**
  - Over 400 annual simulations completed
  - Large quantities of data produced and analyzed
  - Cluster computation resources used

AEP Smart Grid Demo Project