2014 Smart Grid R&D Program Peer Review Meeting

GridLAB-D™ Analysis and Development

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GridLAB-D™ Analysis and Development

Objective

Support industry in using GridLAB-D to quantify the impact of smart grid technologies, such as microgrids, distributed renewables, and new advanced load control strategies. GridLAB-D can simulate 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 FY14	FY14 authorized	FY15 requested	Out-year(s)
$6,500*	$550	$550	
GridLAB-D Development and Support		$400	$400/yr
NRECA GridLAB-D Analysis/Development		$150	
GridLAB-D Analysis – AMI Diagnostics		$220	$500
In FY13, GridLAB-D was divided into multiple projects.			

Technical Scope

Analysis:

- Development of an AMI based diagnostics system.
- The diagnostic system can support accurate dynamic simulation capabilities and/or form the basis for a diagnostic system

Development:

- Ongoing analysis projects,
- User requested enhancements & capabilities,
- Integration/validation of community contributions,
- Outreach and education,
- Formation of Grid Analytics Association,
- Tools for easier use with OMF/NRECA.

Problems and Needs

GridLAB-D is a DOE/OE-funded open-source simulation 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.

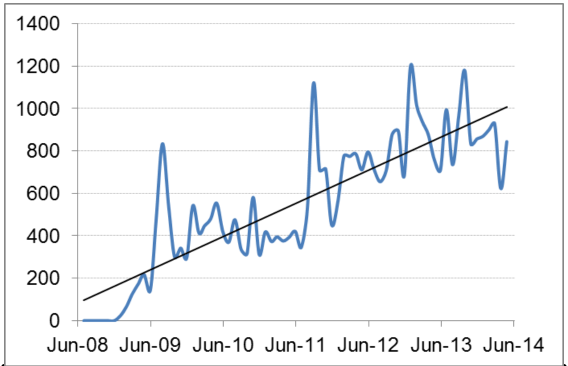
Allows smart grid technology developers to test

- **Microgrids** – Test device controls and efficiency in integrated systems.
- **Distribution automation** – DA technologies can be evaluated and tested extensively before they are fielded in costly trials and demonstrations.
- **Communications, command and control systems** – Tests requirements for necessary 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.

Significance and Impact

Answering emergent issues at major utilities

- AEP, Duke Energy, SCE, NRECA, Ausgrid, SDG&E, etc.
- Detected Volt-Var Optimization and Demand Response control issues prior to deployment



Downloaded 40,000+ times in over 150 countries

Evaluating national-level impacts

- Distribution Automation, Volt-Var Optimization, Demand Response, Distributed Generation, Distributed Energy Storage

Used by major universities to educate the next generation of engineers

- Wash. St. U., U. of Wash., Caltech, Berkeley, Ohio St., MIT, U. of Cal. Irvine, Iowa St., U. of Texas, U. of Illinois, U. of Victoria, etc.

Federation with other tools to enable greater capabilities

- TMO/PRM, DER-CAM, PowerWorld, MATLAB, MATPOWER, FNCS, EnergyPlus, ns3, etc.

Technical Accomplishments (Prior years – Selected Highlights)

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** – Examined the business case for smart grid technologies for rural electric cooperatives.
3. **AEP Demonstration** – Provided detailed simulations in support of the successful RTP rate-case presented to PUCO. Simulated control system (transactive) was used to refine implementation prior to deployment in gridSMART demonstration.
4. **GE CRADA** – Examined the impacts of various smart appliance control strategies for appliance manufacturers, consumers and utilities.
5. **Evaluation of CVR** – Examined national impact of deploying Volt-Var control.
6. **SGIG Analysis** – Examined the performance impact of the SGIG technologies in four principal areas (distribution automation, demand response, renewable integration, and energy storage).
7. **Integrated T&D** – Developed and tested an integrated transmission & distribution control system merging a commercial power flow solver (PowerWorld) with GridLAB-D.
8. **Loads as a Resource** – Evaluated new control design of using aggregation of loads as an emergency frequency regulation resource.
9. **Open Modelling Framework** – Integration of GridLAB-D and additional user tools into OMF, designed to ease the access of capabilities.

Technical Accomplishments (FY 14)

1. **Launched Grid Analytics Association (with NRECA)** to support continued industry investment in open-source analytic tools, such as GridLAB-D.
2. **Supported Open Modelling Framework deployment**
    1. Developed automated model conversion tools.
    2. Developed and testing automated model calibration tools.
    3. Supported use case development (CVR, DG, DS, etc.).
3. **Release of v3.0 and v3.1**
    1. Version 3.0 was released in December 2013 (major API overhaul).
    2. Version 3.1 is scheduled for August 2014 release (enhanced microgrid capabilities).
4. **Technical support and training**
    1. Transitioned to online instruction (webinars, recordings, demos).
    2. Developing additional training modules (v3.0, v3.1, developers, delta, etc.).

Project Team Capabilities & Funding Leverage (Selected GridLAB-D Collaborators FY14)

1. **Other National Labs** – NREL / ORNL / Sandia / LBNL / LLNL.
2. **Washington State University** – Developing restoration and reconfiguration algorithms to support the use of microgrids as a resiliency resource.
3. **NRECA** – Developing/deploying of Open Modeling Framework, an easy-to-use tool for evaluating the business case of new technologies, such as CVR, DG, DS, etc.
4. **Duke Energy/Alstom** – Evaluating the benefits of distributed resources and improving predictions during cold-load pickup events.
5. **SCE & Qado** – Using GridLAB-D to help CA utilities address issues related to high penetration PV by evaluating mitigation technologies (storage, DR, upgrades, etc.).
6. **AusGrid** – Integrated GridLAB-D with DMS to test new control strategies (significant enhancements delivered by AusGrid for v3.1 release).
7. **University of Victoria** – Studied wind integration for BC Hydro & demand response using thermostatic control.
8. **AEP & Battelle** – Expanded transactive market modeling capabilities (and validated performance) and distributed generation and storage controls.
9. **Co-Simulation** – Internally created tool expands capabilities to incorporate communications, detailed building, market, and transmission models.
10. **Education** – Used as a learning platform to introduce undergraduates and graduate students to the analysis associated with smart grid technologies.

Future Plans for Development FY15

1. **Release v3.2** – Minor release to include additional validated microgrid functionality.
2. **Release v4.0** – Major release to include parallelization and performance enhancements, additional hardware-in-the-loop capabilities, improved APIs, and collected developments from the user community.
3. **Support Grid Analytics Association** – Support the fledgling alliance by leading, hosting, and participating in continued formation and growth.
4. **Support user community** – Continue supporting the growing user community through training, outreach, and forum support.
5. **Develop new features** – Work with new Grid Analytics Association and users to identify and implement the most requested features.
6. **Continue bug fixes** – Improve quality of product by addressing bugs that are found in testing and by users.

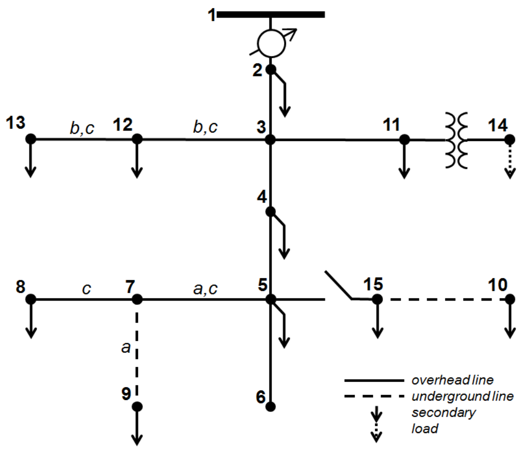
GridLAB-D™ Analysis

- The Analysis portion of GridLAB-D develops limited basic capabilities, only those that are necessary to support specific research goals.

- For FY14 the research areas were;
  - Microgrids as a Resiliency Resource
  - Protection Operations for Resiliency
  - AMI Diagnostics

- Within the dynamic simulations of the first two areas, it is necessary to validate the two major components of dynamic simulation:
  - Generator models
  - System model

- This section will focus on AMI Diagnostics, which attempts to validate the system model.



Problems and Needs

- At the distribution level, there is a lack of observability, and no information redundancy.
- Because of the lack of observability, equipment is generally operated with no knowledge of its operational status or material condition.
- As a result, slow mode failures of secondary transformers and underground cables can occur with little or no warning. In the context of resiliency, this can represent a hidden failure that is only revealed when the system is stressed.
- For distribution system operations and maintenance diagnostics, there is a need for a process to determine the current material condition of equipment.
  - **Hidden Failures**: Ensure that the condition of the system is known so that when a severe event occurs there are no hidden failure mechanisms.
  - **Asset Management**: Provide a basis for effective asset management, and provide information to determine if preventive maintenance and/or replacement is necessary.

Significance and Impact

- AMI measurements have the potential to provide observability at the distribution level, but the data refresh rates are slow. Additionally, the Signal to Noise Ratio (**SNR**) can be very low.

- By concatenating data, off-line, over a period of time, days to weeks, it is possible to address the issue of low SNR and identify small changes in parameter values.
  - **Series**: connectors and splices
  - **Shunt**: cable insulation and shields

- Non-diurnal variations in parameter values can be indicative of slow mode failures such as connector pinpoint arcing or water treeing.

- An AMI based diagnostic system will enable utilities to identify equipment deterioration and to address it before there is a catastrophic failure.

Technical Accomplishments

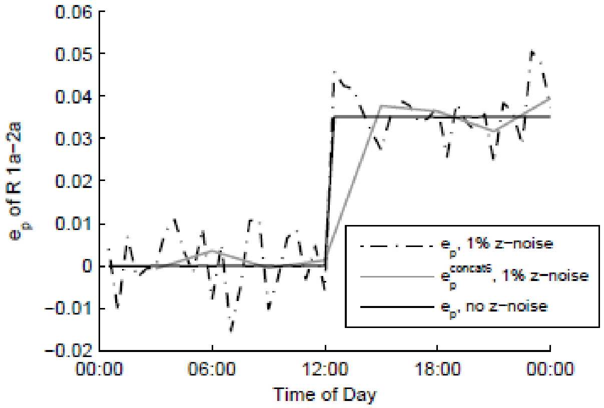
- **Extension of SE**: Extension of the unbalanced state estimation process so that it is based primarily on AMI measurements. This includes the triplex secondary systems.

$$P_m^p = V_m^p \sum_{n=1}^{N} \sum_{q=1}^{3} V_n^q \left[G_{mn}^{pq} \cos(\theta_{mn}^{pq}) + B_{mn}^{pq} \sin(\theta_{mn}^{pq}) \right]$$

- **Fundamental PE**: First attempt at applying AMI based parameter estimation techniques at the distribution level.
  - Residual sensitivity
  - Augmented state vector

$$r_i^N = \frac{r_i}{\sqrt{\Omega_{ii}}} = \frac{(z_i - h_i)}{\sqrt{\Omega_{ii}}} \qquad \lambda_i^N = \frac{\lambda_i}{\sqrt{\Lambda_{ii}}}$$

- **Concatenation of Data**: Because of the low SNR, it is necessary to concatenate multiple time steps worth of data.
  - Concatenation of data improves redundancy and provides improves SNR.
  - The concatenation data window can extend for hour, days, or even weeks.



- **Testing**: the process has been develop using simulated AMI data under multiple operating conditions.
  - Various levels of measurement error
  - Various levels of parameter error
  - Various level of step change in parameter value

Future Plans
FY15

- FY15 will focus on validating the developed methodologies, and developing a full diagnostic system.

- This will include examining the performance on actual utility data that will show potential real world issues:
  - unmetered load
  - poor database values
  - gross topological errors

- The sensitivity of various parameters will be examined:
  - Size of concatenation window
  - Sensitivity to reduced measurements (e.g., only P and Q, no V_{mag})
  - Threshold of detection capability

Contact Information

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