Grid Modernization Initiative
Peer Review
GMLC 1.4.2 – Definitions, Standards and Test Procedures for Grid Services from Devices

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GMLC Peer Review Meeting
Sheraton Pentagon City – Arlington, VA
**Project Description**

Develop characterization test protocol and model-based performance metrics for devices’ (DERs’) ability to provide a broad range of grid services, i.e., to provide the flexibility required to operate a clean, reliable power grid at reasonable cost.

**Value Proposition**

- **Reward innovation**, help manufacturers understand opportunities, enlarge the market for devices
- **Validated performance & value for grid operator decisions** on purchases, programs, subsidies, rebates, markets, planning, operations
- **Independently validated information for consumers & 3rd parties** for purchase decisions

**Project Objectives**

- **Simple, low-cost testing protocols** manufacturers can use to characterize equipment performance (*Recommended Practice*)
- **General, standard device model reflecting test results** for each device class
- **Proven means of estimating performance metrics** for a **standard set of grid services** from the test results
- **Protocol that can be regionalized** to reflect local markets, new services, weather, loads, etc.
## Project Participants and Roles

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Device Class</th>
<th>Grid Services</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>Total</th>
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<tbody>
<tr>
<td>Pacific Northwest National Laboratory</td>
<td>1. Thermal storage</td>
<td>A. Peak load management</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>B. Artificial inertia/fast frequency response</td>
<td>$351K</td>
<td>$440K</td>
<td>$401K</td>
<td>$1,191K</td>
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<td></td>
<td>4. Refrigerators</td>
<td></td>
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<td></td>
<td>5. PV/inverters</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Sandia National Laboratory</td>
<td>6. Batteries/inverters</td>
<td></td>
<td>$106K</td>
<td>$323K</td>
<td>$274K</td>
<td>$703K</td>
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<tr>
<td>Argonne National Laboratory</td>
<td>7. Electric vehicles (DR, V2G)</td>
<td>D. ISO capacity market (e.g., PJM’s)</td>
<td>$141K</td>
<td>$288K</td>
<td>$246K</td>
<td>$675K</td>
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<td>Oak Ridge National Laboratory</td>
<td>8. Res. &amp; Com. HVAC</td>
<td></td>
<td>$146K</td>
<td>$588K</td>
<td>$481K</td>
<td>$1,215K</td>
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<td></td>
<td>9. Com. refrigeration</td>
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<tr>
<td>Lawrence Berkeley National Laboratory</td>
<td>10. Commercial lighting</td>
<td>E. Regulation</td>
<td>$211K</td>
<td>$263K</td>
<td>$226K</td>
<td>$700K</td>
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<tr>
<td></td>
<td></td>
<td>F. Spinning reserve</td>
<td></td>
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<td>G. Ramping</td>
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<tr>
<td>Idaho National Laboratory</td>
<td>11. Fuel cells</td>
<td>H. Wholesale energy market/production cost</td>
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<td></td>
<td>12. Electrolyzers</td>
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<td>$146K</td>
<td>$313K</td>
<td>$266K</td>
<td>$725K</td>
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<tr>
<td>Totals</td>
<td></td>
<td></td>
<td>$1,420K</td>
<td>$2,731K</td>
<td>$2,350K</td>
<td>$6,500K</td>
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</table>
✓ **Project is central to a number of tasks in the Devices and Integrated Systems MYPP:** grid services, unified models, testing procedures and contributes to many more.

- **Definition of grid services & representative drive cycles**
- **Battery equivalent model defines flexibility, unifies DR & DER models**
- **Device models & validation test results contribute to testing library**

### Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Relationship to Grid Modernization MYPP

#### Activity
- **Devices and Integrated Systems**
  1. Develop advanced power electronics, energy storage systems, controllable loads, etc.
  2. Develop Standards and Test Procedures
     - 2.2.6. Develop standard set of definitions for full range of grid & ancillary services
     - 2.2.8. Develop technology neutral consensus-based standard for providing grid services
     - 2.2.9. Develop testing procedures for evaluating ability of devices to provide grid services
     - 2.3.4. Develop unified model description for devices that can provide grid services
     - 2.3.6. Develop models for storage & loads; populate library based on testing results
     - 2.3.7. Develop open simulation framework with composable & interoperable models
     - 2.3.11. Validate testing procedures for ... grid services
  3: Build Capabilities and Perform Testing and Validation of Devices
Characterization Protocol
- Measure device fleet parameters describing ability to provide grid services
- Simple, short (<24-hr, inexpensive) procedure, complementing existing test protocols: How much, how fast, how long, time lags, etc.

Model Device Fleet
- Time series model of device fleet performance
- Based on measured parameters
- Base case end-use load that must be served
- User and device limitations and requirements
- Express as battery equivalent parameters to grid services model
- Measures of consumer and device impacts

Define Grid Service
- Definition and purpose
- Requirements of providing devices
- Representative time-series “drive-cycle” of the service

Grid Service Dispatch Model
- Scale fleet of identical devices to service based on nominal power of devices and peak power required by service
- Simple, direct control of battery-equivalent fleet of identical devices

Performance Metrics
- Grid service performance metrics
- Consumer impacts (energy, comfort, amenity)
- Device impacts (cycles/yr, etc.)

Key Challenges: 1) General battery equivalent model for all devices/services, 2) Modular design & assumptions allow regionalization
### Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Key Project Milestones

<table>
<thead>
<tr>
<th>Milestones* (FY16-FY18)</th>
<th>Status</th>
<th>Due Date</th>
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</thead>
<tbody>
<tr>
<td>1. Standard definitions &amp; drive cycles for grid services (draft for industry review)</td>
<td>1. Complete</td>
<td>October 1, 2016</td>
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<tr>
<td>2. General device model (draft for industry review)</td>
<td>2. Complete</td>
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<tr>
<td>3. Extrapolation procedure for performance of grid services</td>
<td>3. Complete</td>
<td>April 1, 2017</td>
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<tr>
<td>4. Draft Recommended Practice (vetted with industry)</td>
<td>4. Underway</td>
<td>October 1, 2017</td>
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<tr>
<td>5. Trials of device characterization protocols (for each device class)</td>
<td></td>
<td>April 1, 2018</td>
</tr>
<tr>
<td>6. Manufacturers review of characterization protocol &amp; test results</td>
<td></td>
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<tr>
<td>7. Proof-of-concept testing validates extrapolation procedure</td>
<td></td>
<td>October 1, 2018</td>
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<tr>
<td>8. Stakeholder group consensus that Recommended Practice is useful &amp; accurate</td>
<td></td>
<td>April 1, 2019</td>
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Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Accomplishments

General Framework and Approach

- Device & Controller Under Test
- Characterization Test & Apparatus
- Existing Industry Standards
- Std. Device Assumptions
  - Baseline usage, Balance of System, Limits
- Updated Parameters
- Adopted Parameters
- Device Model
- Battery-Equivalent Model
- Grid Service
  - Grid Service Drive Cycles
  - Weather, Boundary Conditions
- Performance Metrics
  - Dispatch Fleet
  - Advance through drive cycle time steps
  - Service Efficacy & Value Metrics; Energy, End-User, Equipment Impacts

Devices and Integrated Systems Testing

5/11/2017
Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Accomplishments

Define Generic Devices: Power Flows & Services

Power Balance:
\[ P_{\text{Grid}}(t) = P_{\text{Output}}(t) + P_{\text{Discharge}}(t) - P_{\text{Enduse}}(t) - P_{\text{Parastic}}(t) \]

Power for Grid Service:
\[ P_{\text{Service}}(t) = P_{\text{Grid}}(t) - P_{\text{Grid Base}}(t) \]
where Base indicates base case
\[ P_{\text{Service}}(t) = \Delta P_{\text{Discharge}}(t) + \Delta P_{\text{Output}}(t) - \Delta P_{\text{Enduse}}(t) - \Delta P_{\text{Parastic}} \]
where \( \Delta \) is the difference between the service case & base case
### Recommendation

This project needs a lot more support from industry. The meeting in March 2017 is critical.

### Response

**Organized series of webinars & briefings** to raise awareness leading up to 2\(^{nd}\) Industry Workshop:

- GridWise Alliance pre-workshop webinar (n = 35*)
- Commercial lighting webinar (n = 27*)
- PV/batteries/inverters webinar (n = 321*)
- HVAC & appliances webinar (n = 21*)
- Thermal energy storage briefings (n = 2*)
- Electric vehicle industry meeting presentation (n = 13*)
- More webinars to come in April (fuel cells/electrolyzers)

**Partnered with the GridWise Alliance to host 2nd Industry workshop** with sponsors GE & Intel @ GE’s GridIQ Center in Atlanta GA March 21-22, 2017 (n = 36*)

* Count excludes DOE and national laboratory participants

- ✓ Project has raised industry awareness of the project dramatically in Q1&2 FY17
Relationship to Other GMLC Projects

- Defining grid services, & metrics for grid services are value based (1.2.4 & 1.4.27)
- Use virtual battery concept as common device model interface to each grid service (GM61)
- Device models & grid service performance models useful for long-term planning (1.3.5, 1.4.25 & 1.4.26)
- Interoperability & Interconnection (1.2.2 & 1.4.1)
- Test procedures, data, & device models delivered to GMLC Testing Network’s test procedure repository library (1.2.3)
- Leverage testing & interoperability for electric vehicles (GM85 & GM86)

Engagements

- 1st Industry Workshop – 9-12-17, NREL
- 2nd Industry Workshop – 3-21/22-17, Atlanta
- 4 device-class & services webinars – Mar ‘17
This project is about:

- Enhancing
- Empowering
- Unlocking
- Unleashing

the value of grid modernization devices everywhere!

**Oct’17:** Draft *Recommended Practice*, vetted by utility & device industries

**Apr’18:** Test rigs & trials of characterization protocol, each device class

**Apr’19:** Proof-of-concept testing of measured device performance against actual grid services

**Impact:**
- Std. performance, value & impact metrics for devices providing grid services
- Reward innovation, sell more devices
- Better decision-making by consumers, utilities, 3rd parties
- Lower cost, more reliable, cleaner grid

**Expansion Potential:**
- Battery equivalent interface as a modeling standard
- Allows detailed, state-of-the-art device models to plug & play into planning and operation tools
Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Data Flow between Device Model and Grid Service: the Battery Equivalent Model

**Device Model**

- Inform Service of Constraints
  - Nameplate capacity
  - Energy storage capacity
  - Energy stored
  - Charging efficiency
  - Discharging efficiency
  - Maximum power for service
  - Minimum power for service
  - Ramp rate power up
  - Ramp rate power down
  - Time limit, hold
  - Time, restoration
  - Strike price
  - Price elasticity
  - Power injected into grid, basecase

**Grid Service**

- Initiate exchange for time interval
  - Current time
  - Time interval
  - Weather data

- Dispatch the service for time interval
  - Power delivered for service
  - Power injected into grid

**Steps**

1. **Step 1**
   - Initiate exchange for time interval

2. **Step 2**
   - Dispatch the service for time interval

3. **Step 3**
   - Dispatch the service for time interval
Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Design Principles & Functional Objectives

► Test protocol simplicity
  - Short duration, low cost
  - Leverage/complement existing standards

► Test once, rate many
  - Extrapolate test results to grid service via device model
  - Allow new services to be defined, rated

► Device performance as member of a fleet
  - Individual devices may not have fidelity required for a service

► Uniformity across device classes & grid services
  - Common dispatch & performance metrics agnostic to device type
  - Normalize performance to device nameplate capacity

► Support customized assumptions to reflect a region
  - Weather, balance of plant, baseline usage assumptions
  - Grid service “drive-cycle” patterns & values & value streams
 Purpose: Determine fundamental electrical properties of device & any autonomous responses.
**Purpose of test:** Characterize curtailment capabilities: e.g., amount of power curtailed, time lag, effect on energy consumption, etc.

**Load Curtailment Characterization**

- 100% load reduction (1.8 kW)
- Time lag = 2 min.
- **Metrics**
  - Absolute load reduction
  - % load reduction
  - Time lag from request to curtailment

**Curtailment Characterization with Recovery**

- Recovery energy = 92% of shifted energy
- Temp. limit reached

**Metrics**

- 92% recovery energy
- 5°F temp. rise limit
- 5-hr mode time limit (not shown)
**Purpose of test:** Characterize load following capabilities, i.e., ability to follow load-up/load-down signals at increasingly short intervals (for ancillary services, renewables integration, etc.)

**Load Following Test (kW)**

- **Baseline period, with 50% duty cycle**
- **Transition to middle of curtailment range**
- **8-min. test**
- **4-min. test**
- **2-min. test**

**Example Metrics**

- 104% recovery energy (not shown)
- 100% load following, down 2-minute intervals
- Time lag (2-min)