Stanford University

SLAC NATIONAL ACCELERATOR LABORATORY

System Validation

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Outline

- Validation Plan
  - Generalities
  - Analytical Models
  - High Level Simulator – GridLAB-D
  - Navy base Residences
- Component Validation
- Performance Tests – Aggregation

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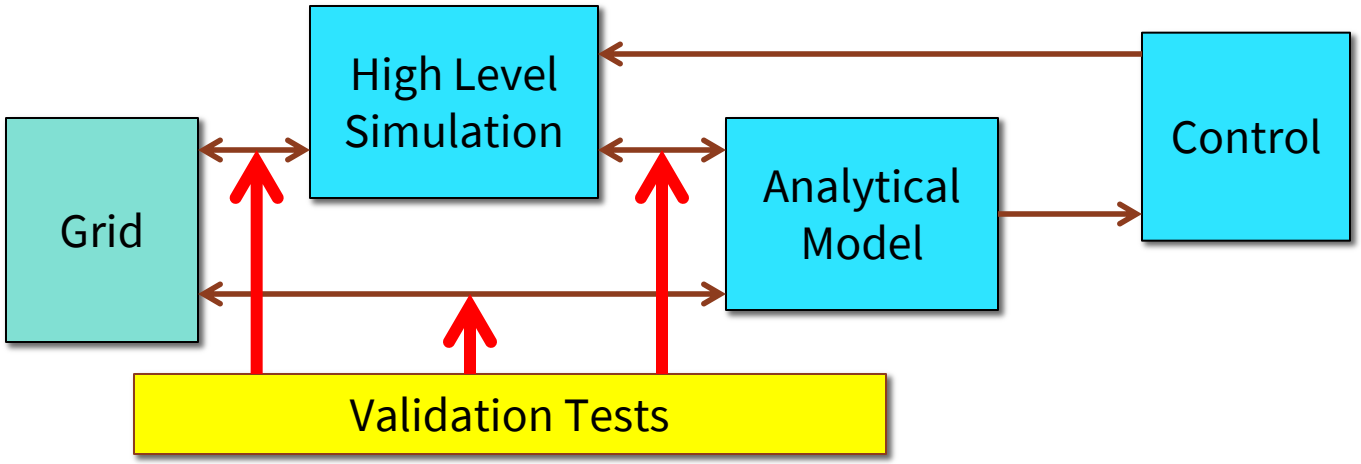
Validation Plan – Modeling - Generalities

- Large Scale Projects requires 3 steps or main elements for modeling and validation.
  - Analytical or Reduced Model
  - Large Scale Simulation Tool
    - GridLAB-D + Labs – GridLAB-D + Residence (San Diego site)
  - Real System (Grid)



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Validation Plan – Modeling - Generalities

- The goal of the Validation Plan & Tests is twofold:
  - Reach agreement between the model dynamics and the real system
    - Based on system measurements.
    - Define a base line where results in simulations are directly deployed into the real system
    - Mainly define/test analytical models for the devices and extend to the high level simulator (GridLAB-D)
  - Define generic tests to verify the system stability and performance
    - Broad performance goals to be fulfilled by the system under different scenarios (12 scenarios)
      - High and moderate solar penetration (50% - 15%)
      - Presence or absence of regulation signals
      - Normal, peak and outage conditions.

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Validation Plan – Modeling - Analytical Model

- Define V-I-P-Q characteristics (e.g. ZIP model) of multiple individual devices in a home (Appliances, storage, generation, etc.)
  - Identify main dynamic model – Define daily time of use for aggregation.
  - Study characteristics of loads under voltage variation (smart dim-fuse operation)
- Validate appliances, storage, generation, etc. models in GridLAB-D.
  - Compare with real measurements of devices used in the project.
- Validate the measurement system and communication protocols used by the Home Hub – Impacts of delay and set of variables measured.
  - Define model to be included in GridLAB-D
- Define analytical model at the house level – Study and classify load variations and schedule.
  - Using 1) Simulation
  - 2) Simulation + HH + Labs
  - 3) Simulation + HH + Navy residences + Labs

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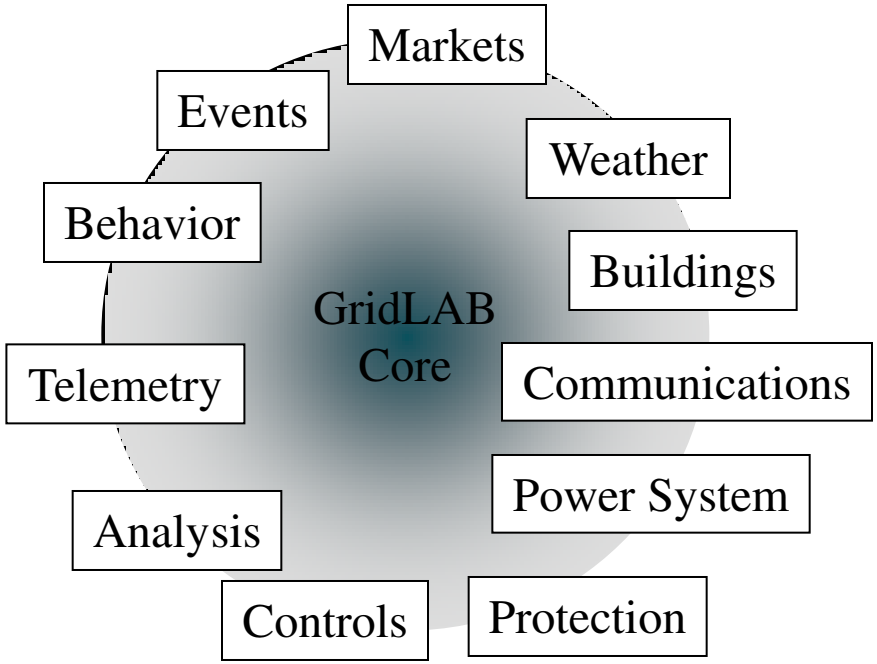
Validation Plan – Modeling – High Level Simulation: GridLAB-D Architecture



- Developed at Pacific Northwest National Laboratory (PNNL)
- Funded by the DOE/OE
- Open source platform since 2007

GridLAB-D Core functionality

- Integrates multidisciplinary models
- Manages memory & CPUs
- Coordinates time across simulations
- Handles stochastic behavior
- Synchronizes updates
- Coordinates variable sharing
- Manages convergence
- Tracks numerical stability
- Measures system performance
- Debugs module behavior

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Validation Plan – Modeling – High Level Simulation: GridLAB-D in PowerNet

- Hardware-in-the-loop

  Supports integrated seconds-to-hours HIL simulations

  - Feeder operations
  - Retail tariffs
  - Building thermal energy and appliances
  - Distributed resources
  - Demand response

- Scaling-up laboratory-scale experiments

  Enables multi-scale modeling

  - Bulk system response
  - Area control and regulation
  - Retail-wholesale market integration
  - Distribution system operations

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Modeling - High Level Simulation + Residences Election of Navy site

- Two options were picked by Lincoln Military Housing (LMH).
  1. Vista Ridge Housing
  2. Chesterton Housing

  - Single residence units, both equipped with PVs and A/C.
  - LMH prefers Vista Ridge Housing over Chesterton Housing because the last site is under renovation
  - Both homes are outside the fenced area within the San Diego community. Both are power metered by SDG&E

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Residence Election at Navy site: Vista Ridge Housing

- 24 homes arranged in 13 units (2 single / 11 Duplex duplex side-by-side, equipped with PVs and A/C and individual power metering

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Validation Plan – Component Validation

- Smart Dim Fuse
  - Features: Switch ON/OFF, safety and power control
- Hardware in the Loop (HIL)
  - 10-20 houses including 100+ devices and appliances.
  - Cost minimization and regulation scenarios will be used to quantify resource size, availability, response, etc.
- Cloud Coordinator (CC)
  - Regulation Signal formulation validation
  - Validation of the integrated solvers in the cloud for ramping and regulation
- Market Design
  - Market models and payment mechanisms
- Test and validate the HIL and CC functionality and performance for cost, ramping and regulation

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Validation Plan – System Validation - Aggregation

- All previous elements will be integrated and validated in GridLAB-D.
- Aggregation will be analyzed based on the ANALYTICAL MODELS and the HIGH LEVEL SIMULATION (GridLAB-D)
  - 100 – 10,000 residences will be model in GridLAB-D, based on validated models of Lab and Navy houses
  - GridLAB-D will include, smart dim-fuse, hardware in the loop, market models and cloud coordinator.
  - Studies will cover the 12 different scenarios to test performance
    - High and moderate solar penetration (50% - 15%)
    - Presence or absence of regulation signals
    - Normal, peak and outage conditions.

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Appendix 1: Validation Plan – Performance Metrics

- OPF cost minimization: total cost reduction > 10%

- For Ramping
  - Initial time response < 10 min
  - RMT > 10% RMVT < +/- 5%
  - Ramp Time <30 Min
  - Duration > 3 hrs
  - Availability > 95%
  - Recovery Time < 4hrs

- For Regulation
  - Initial time response < 5 sec
  - RMT > 5% of load RMVT < +/- 5%
  - Ramp Time < 5 Min
  - Duration > 30 min
  - Availability > 95%

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