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Distributed Energy Resource Management Solutions to Enable Reliable and Resilient Distribution Grids

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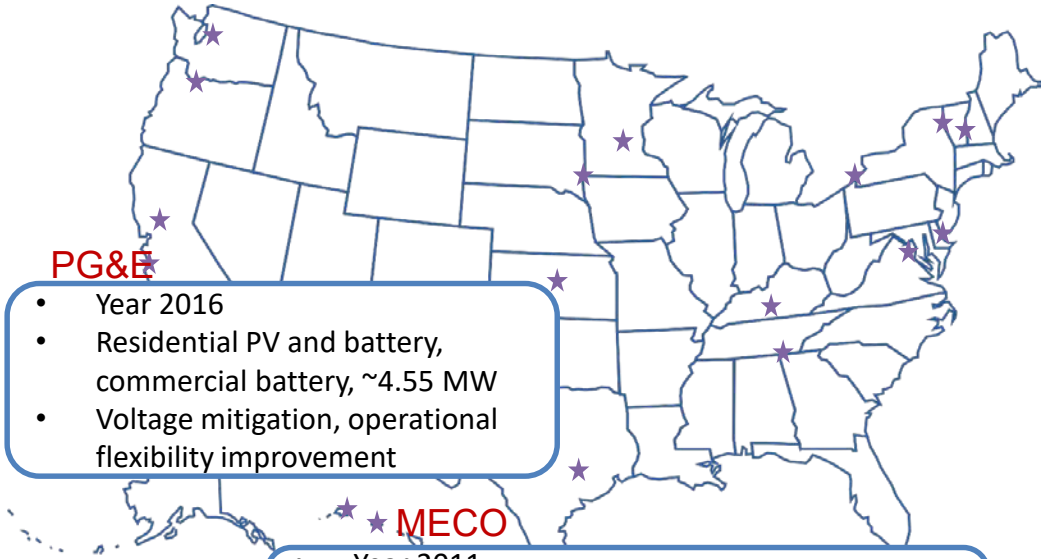
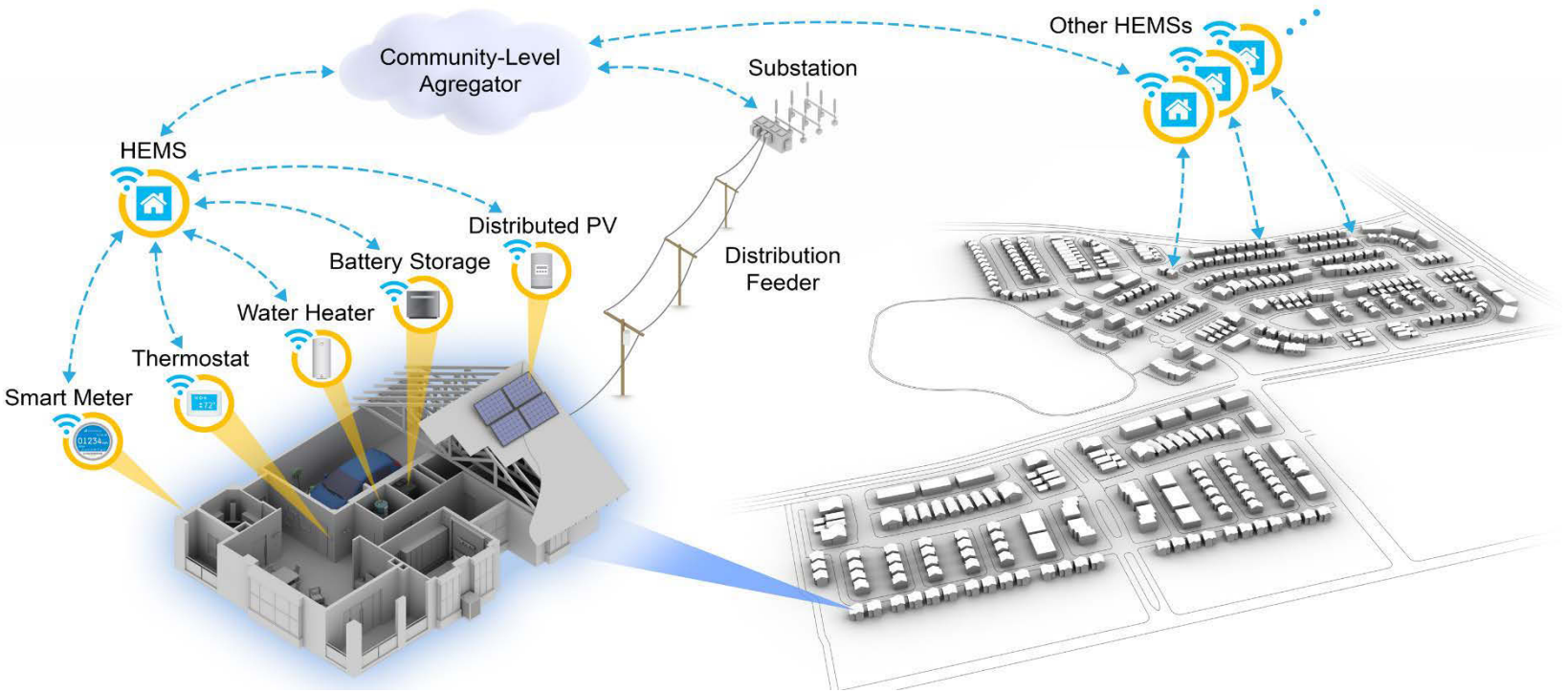
❑ 23 utility-led DER aggregation since 2009*.



- Lack of situational awareness and observability of BTM DERs
- Lack of cost-effective and interoperable DER management system solutions to integrate and control DERs
- Lack of methods to increase communication reliability and security
- Difficulty in recruiting customer participations

*J. Cook, K. Ardani, E. O'Shaughnessy, B. Smith, R. Margolis. 2018. Expanding PV value: lessons learned from utility-led distributed energy resource aggregation in the United States, Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71984.



- Physics-based and data-driven load modeling
- HEMS to directly control BTM DERs
- Hierarchical control for enhancing grid reliability and resilience

Physics-based modeling in BEopt to inform reduced-order models and DER sizing

BEopt
Building Energy Optimization
with Hour-by-Hour Simulations
NREL
National Renewable Energy Laboratory

Large single-family detached

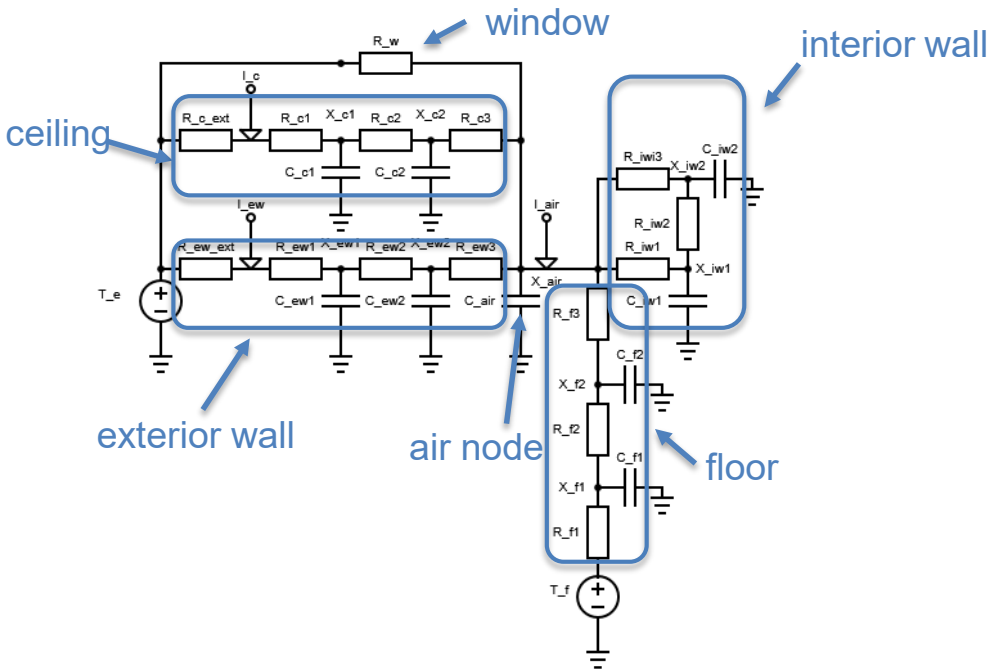
Cottage

Two-story townhomes (3-unit)

Three-story townhomes (3-unit)

Duplex (2-unit)

Develop reduced-order models for controllable building loads to enable large-scale building-to-grid studies



9-node RC model for building envelope

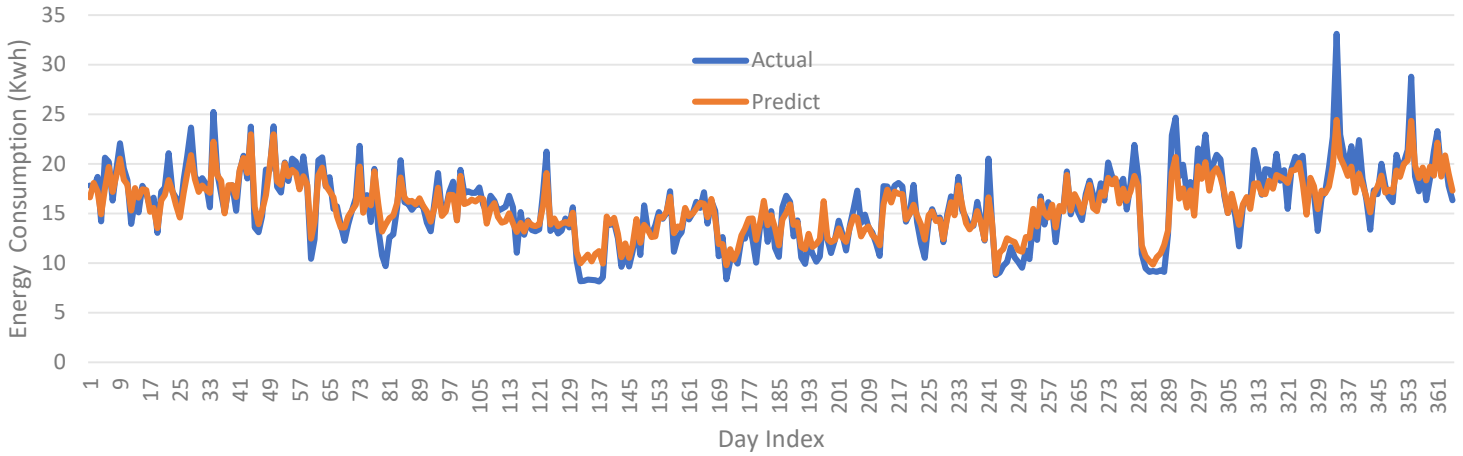
Component Model Structure:

- Exterior wall: 4R2C
- Ceiling: 4R2C
- Window: 1R
- Floor: 3R2C
- Interior wall: 3R2C
- Air node: 1C
- **Total**: 15R9C

Data-Driven Approach to Estimate Non-Dispatchable Load

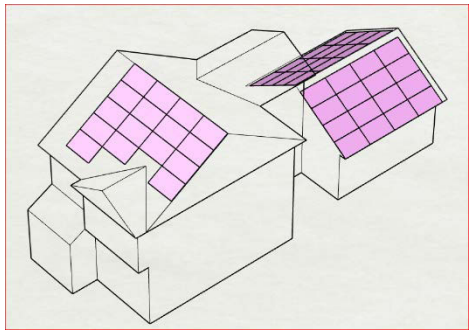
Algorithm Performance Comparison

Algorithm Name	Training			Testing		
	MAE	RMSE	R^2	MAE	RMSE	R^2
Bin Average Method	-	-	-	0.209	0.311	0.373
Multiple Linear Regression	0.159	0.251	0.613	0.158	0.242	0.600
Neural Network	0.144	0.228	0.656	0.153	0.246	0.632
Gaussian Process	0.146	0.232	0.662	0.147	0.231	0.640
Random Forest	0.123	0.200	0.753	0.217	0.315	0.325
Support Vector Regression	**0.146**	**0.233**	**0.664**	**0.143**	**0.228**	**0.657**

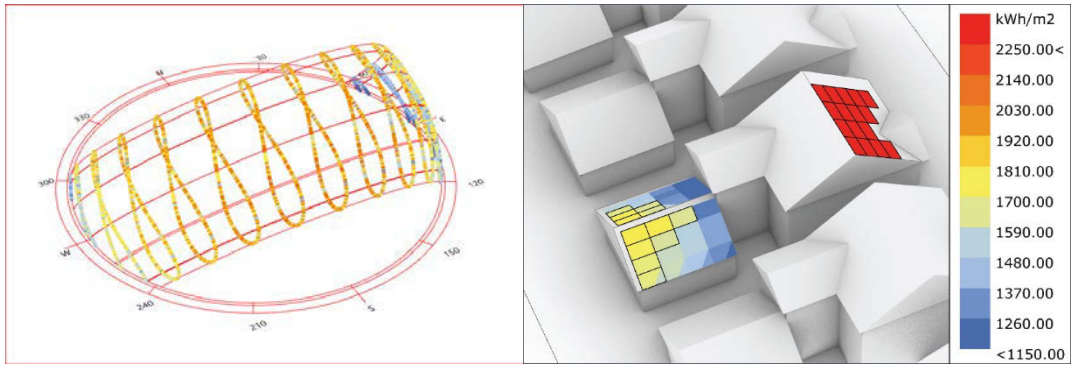


Estimation of non-dispatchable load

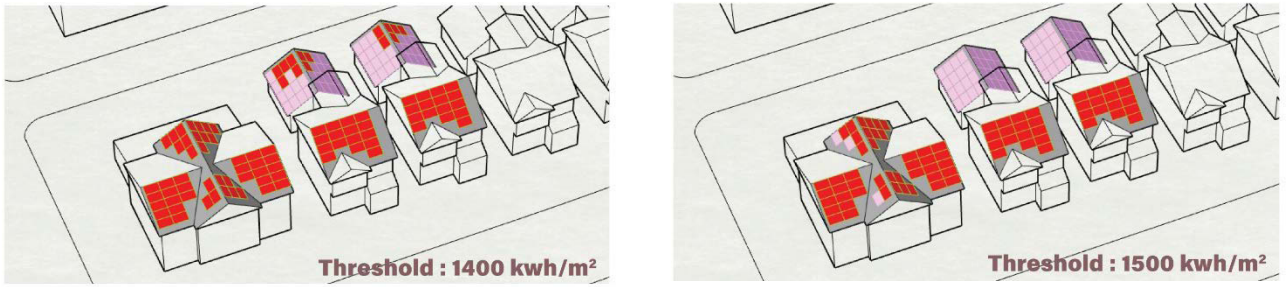
Optimal PV Panel Placement and Sizing



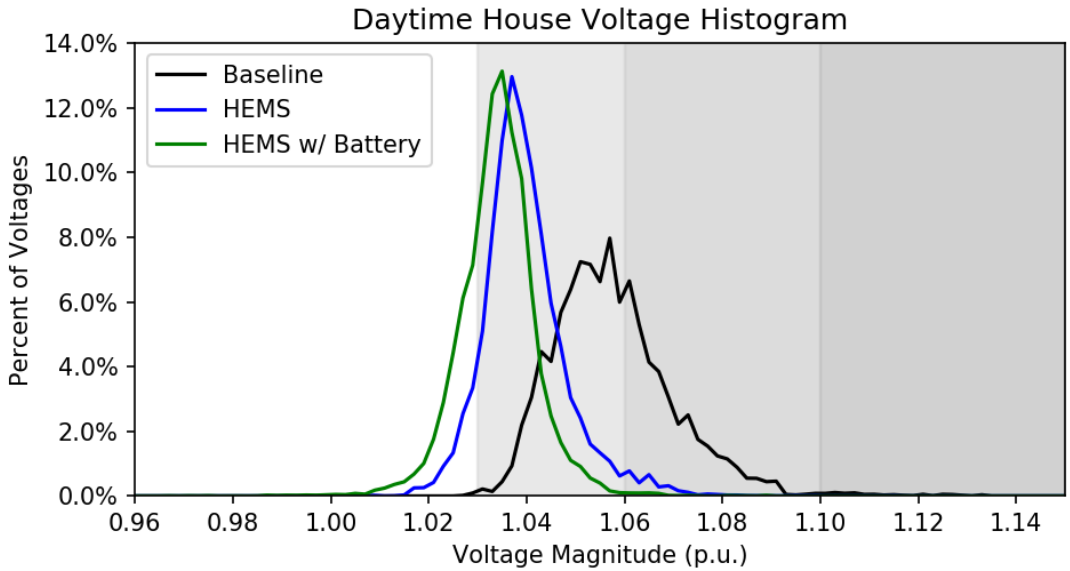
(a) Automated PV panel layout considering roof geometry and panel size

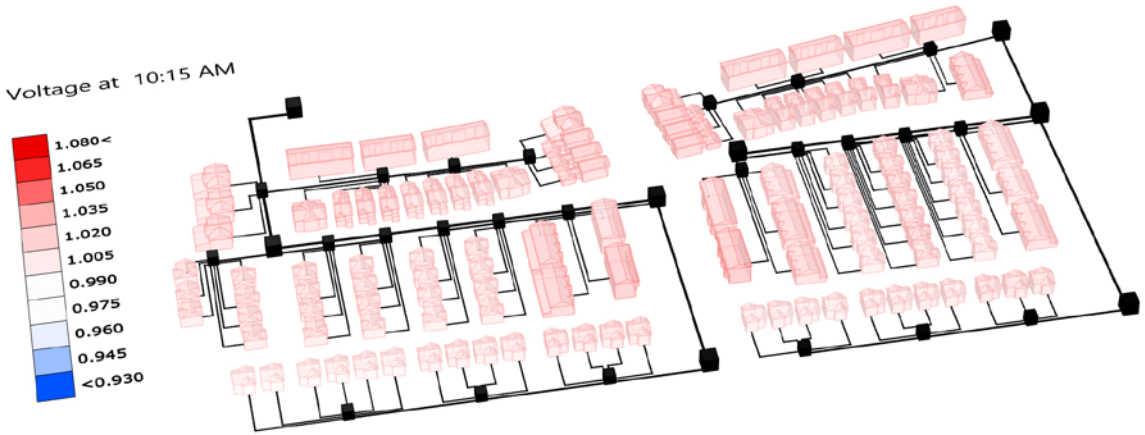


(b) Compute the annual solar radiation (kWh/m^2) on each panel

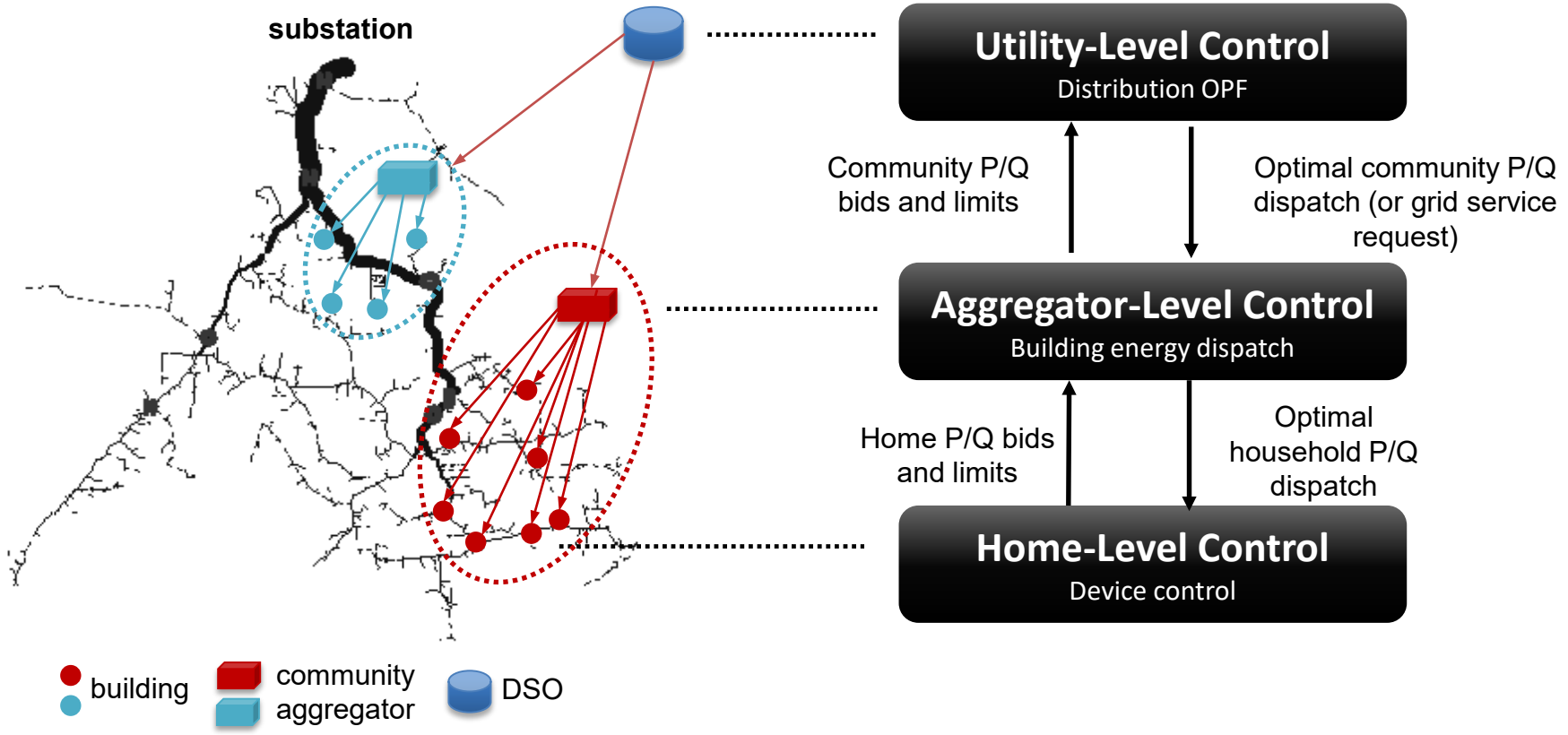


(c) Identify best locations for panel deployment based on a solar radiation threshold

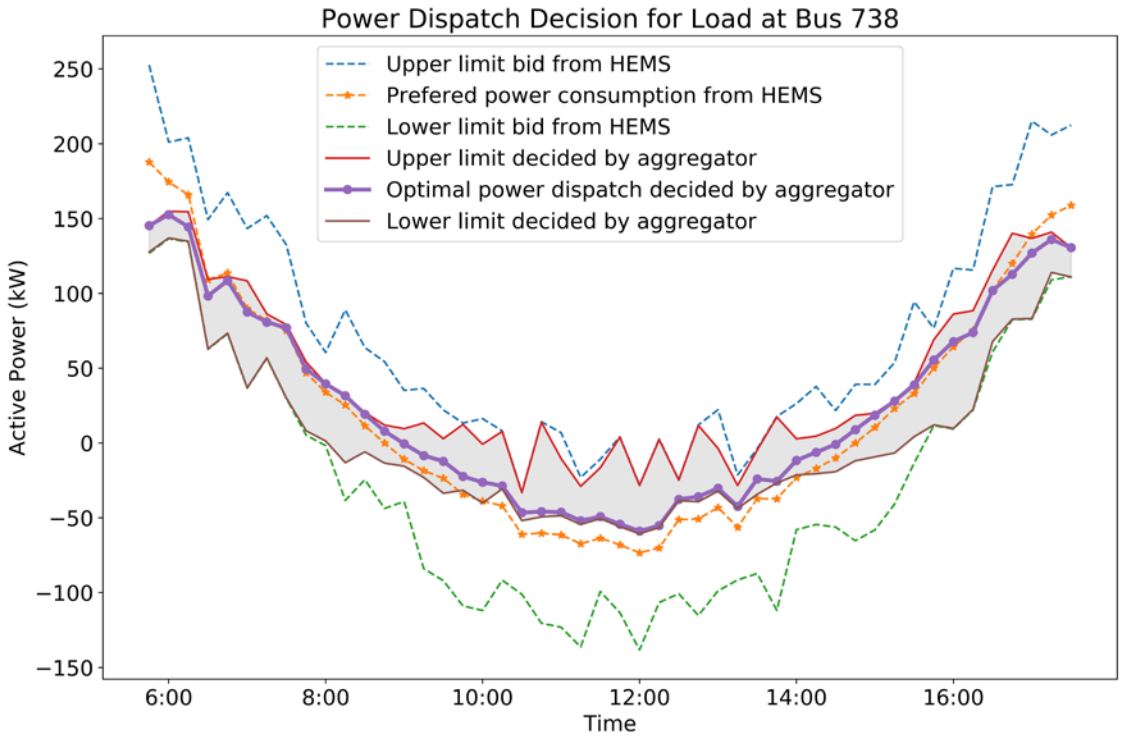

Daytime House Voltage Histogram
Baseline
HEMS
HEMS w/ Battery
Percent of Voltages
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
0.96
0.98
1.00
1.02
1.04
1.06
1.08
1.10
1.12
1.14
Voltage Magnitude (p.u.)

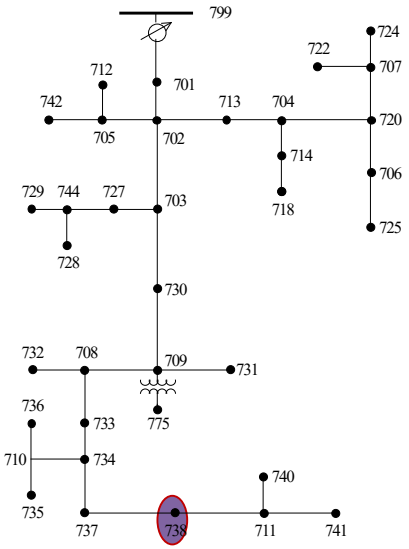

Voltage at 10:15 AM
1.080<
1.065
1.050
1.035
1.020
1.005
0.990
0.975
0.960
0.945
<0.930

Hierarchical Control for Coordinating DERs to Provide Grid Services



Simulation Test on IEEE 37-Bus Feeder





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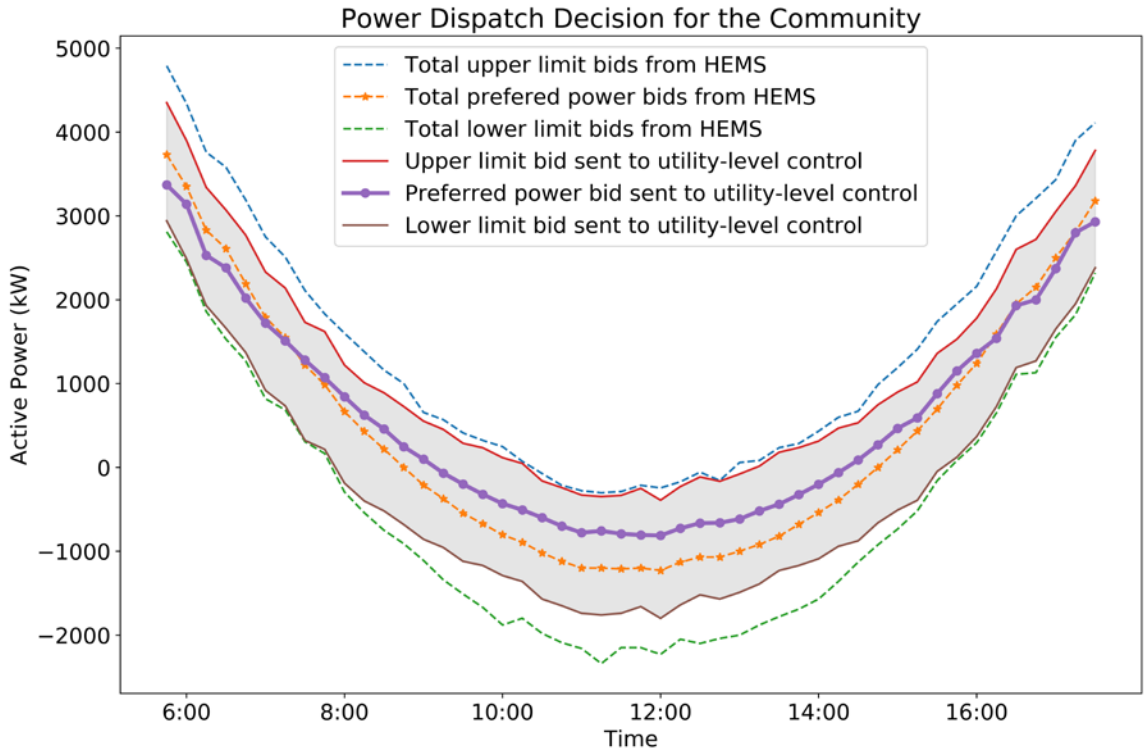
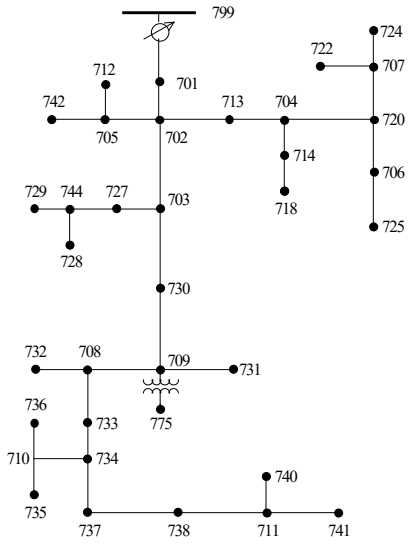
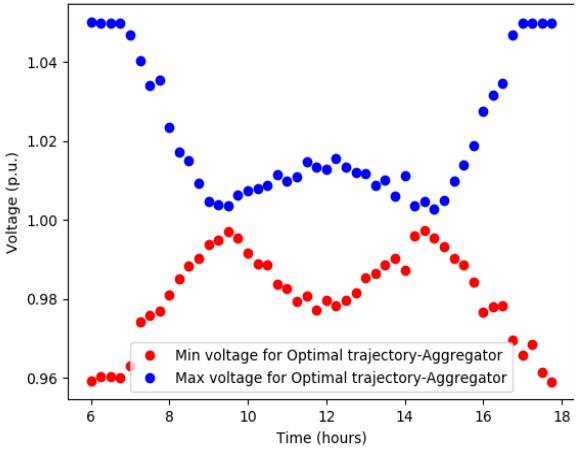
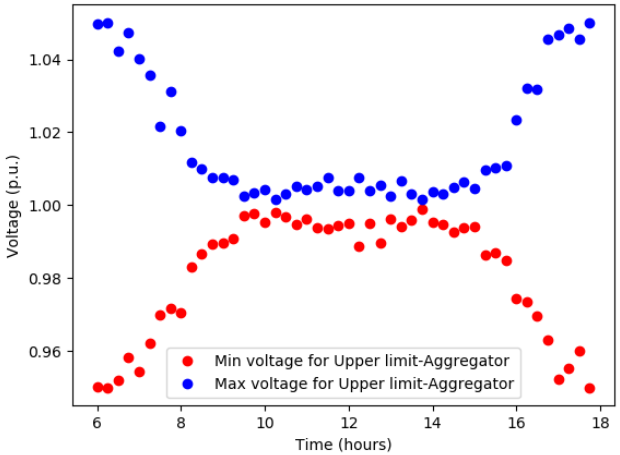
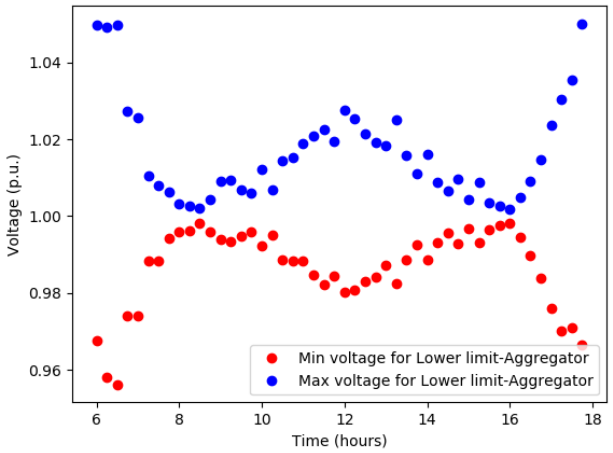




Simulation Test on IEEE 37-Bus Feeder

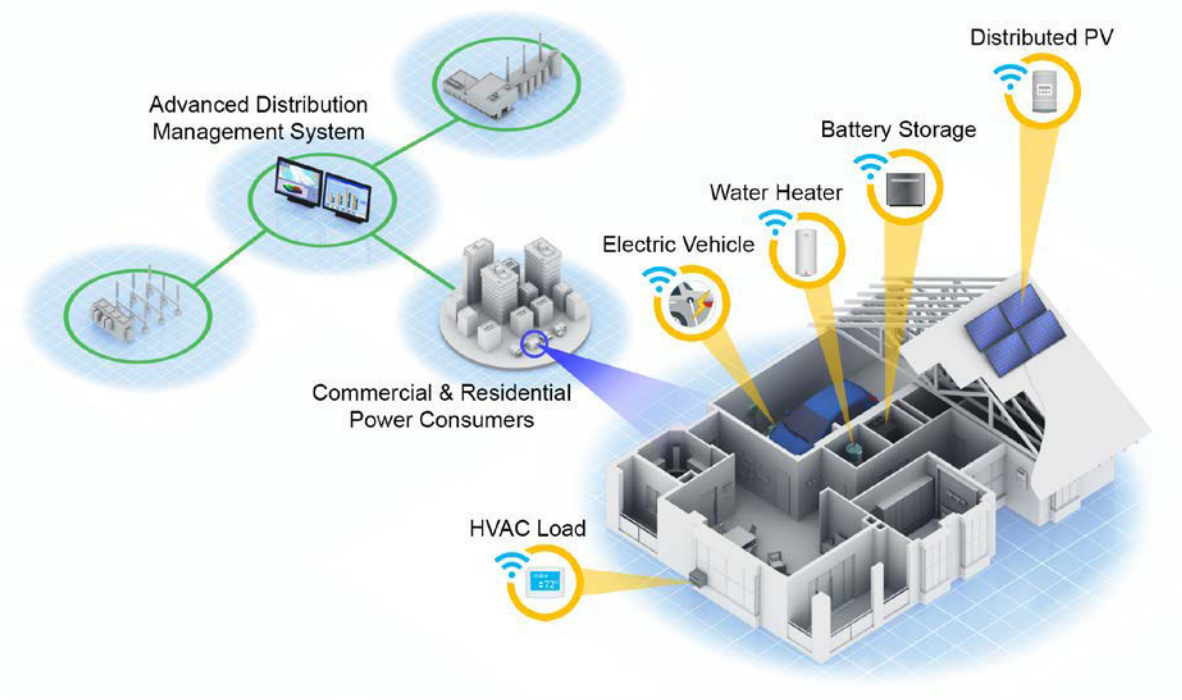


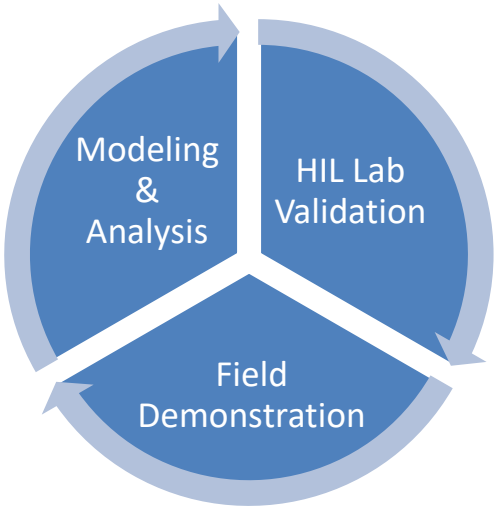




Within aggregator P/Q trajectory ranges, the entire network voltage is always satisfying operational limits.

DERMS + ADMS


Distributed PV
Advanced Distribution Management System
Battery Storage
Water Heater
Electric Vehicle
Commercial & Residential Power Consumers
HVAC Load


Modeling & Analysis
HIL Lab Validation
Field Demonstration

HIL Experiment

Field Demonstration

Critical Support

- DER owner participation
- Transactive Approach
- Distribution Service

Thank You!

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