TIP 337: Home Battery System for Cybersecure Predictive Energy Efficiency and Demand Response

Context

Residential buildings present a significant but challenging opportunity for grid operations. Homes comprise over 90% of a utility's customers and in aggregate are both the largest energy-consuming sector and the driving force behind most utilities' peak loads. In many markets, the residential sector has the largest contribution to the peak load, much more so than during off-peak times.

Utilities often approach the residential demand response (DR) problem solely by providing financial incentives. Pricing mechanisms include direct load control (DLC) programs, rebates, and various dynamic pricing schedules, including time-of-use (TOU) and real-time pricing (RTP). Additional DSM programs usually entail pamphlets distributed with information on recommended behaviors for energy savings. These techniques often produce fewer savings than anticipated and for only a limited duration.

Aggregation of distributed energy resources promises some relief, but has yet to achieve significant adoption. Specifically, a number of adoption barriers exist – cost of implementation, perception of utilities circumventing homeowner preferences such as comfort, operating cost and technical hurdles in managing many small distributed loads, data privacy, and cybersecurity, to name a few.

Description

This project, led by National Renewable Energy Laboratory (NREL) developed and demonstrated an innovative Home Battery System which provides electric energy storage and conversion, along with self-learning adaptive control signal outputs for appliances and reliable predictions for residential demand response. The team performed preliminary validation of critical infrastructure protection (CIP) requirements on the Home Battery System. The work resulted in improved understanding of the system performance and cost tradeoffs. The project made substantial progress toward a marketable product, but may not result in a market-ready Home Battery System product.

Major project tasks included:

- Development of control platform architecture and data model
- Development of Homeowner Preference Input methodologies
- Development of advanced, self-learning controls for individual appliances, and hierarchical control methods for the whole-home, enabling optimal operation to deliver comfort alongside demand response
- Development of hardware including: Home Battery System, controller and DR-ready appliances
- Laboratory demonstration of the Home Battery System, along with several connected appliances, to deliver reliable forecasts and whole-home demand response without significant homeowner impacts
- Cybersecurity (CIP) integration and validation
- Reporting on the project's results and outcomes

Benefits

For BPA, the Home Battery System can support a distributed energy resource available for grid services including balancing, contingency and regulation; thus reducing demands on the hydro system. For the homeowner and utilities this project can facilitate energy efficiency through advanced learning controls and by enabling higher utilization of renewable energy (i.e. avoidance of curtailment).

The flexibility of the Home Battery System allows utilities to call either INC or DEC services with a variety of timescales and durations. Managed properly, this can be a valuable part of system congestion management.

The learning controls accommodate grid DR requests, and when no event is underway they will optimize for energy savings in order to maximize the cost benefit to the homeowner. In this way, operation of the Home Battery System will maximize operating efficiency of the home most of the time, while being available for grid needs whenever called.

Accomplishments

This project developed a Home Battery System integrated with advanced control algorithms for cybersecure energy efficiency and demand response. The system can provide highly available and reliable DR resources while maintaining comfort and energy efficiency in a home.

Deliverables

This project provides documentation of all software records and schematics.
The final report covers all the technical details and lessons learned.

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Project Start Date: October 2015

Project End Date: May 2018

Reports, References, Links

Final Report:
https://www.nrel.gov/docs/fy19osti/72184.pdf

Participating Organizations

National Renewable Energy Laboratory (NREL)
Robert Bosch, LLC

Funding

Total Project Cost: $2,500,000

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Conclusions

The Home Battery System concept—automating flexible loads as an active EE and DR asset for customer and grid benefits—actually works. Excepting several clear opportunities where further development and platform maturing is needed, the application of multi-criterion decision making results in significant homeowner savings, energy savings, and DR service outcomes.

- Energy Efficiency : 0.4–8.1 kWh/day savings, when no DR called (4%–50% utility cost savings)
- Demand Response : 5.0–6.3 kWh over 4-hour DR period (INC and DEC)
- Energy Export : Hawaii cases all export significantly less with ***foresee***™***,*** home energy management system. Washington/Oregon cases generally export slightly more.
- Multi-criterion Decision Making : Clear differences in execution, but room for improvement exists.
  - Cost savings preference did lead to lowest utility costs (and lower battery wear)
  - Negative comfort impacts are apparent in most cases, which motivates further model development to improve thermal predictiveness.

Most notably, energy was saved in every scenario and case where the ***HBS*** and ***foresee*** were able to optimize the home. Cost was saved in every EE case, and (compared to the Baseline) in many DR cases—despite the fact that we did not account for any utility incentive for DR in calculating the daily cost.

foresee was demonstrated to operate successfully on a microcomputer, which shows promise for a future transition to an embedded application and/or operation of numerous simultaneous instances in a cloud setting. The platform's cybersecurity layer proved capable of handling the advanced penetration testing successfully, aside from a vulnerability that existed to facilitate early prototyping, and would not exist in a final product instance.

In parallel projects, and a DOE-funded extension, we have seen that application of ***foresee*** to other operational scenarios is possible (e.g. Cutler et al. 2018; Laws et al. 2018); extending the ***HBS*** to other equipment configurations is possible (e.g. Baker et al. 2016); and studying annual outcomes and establishing financial metrics to justify its adoption will be valuable (e.g. Jin, Maguire, and Christensen. 2018)