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AI-based Optimal Design and Controls Can Greatly Reduce Carbon Emissions and Enhance Resilience in Residential Communities in Cold Climates

AI-Driven Smart Community Control for Accelerating PV Adoption and Enhancing Grid Resilience

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Partners:

- Habitat for Humanity Roaring Fork Valley
- Holy Cross Energy
- Copper Labs
- Conservation Labs
- Thrive Home Builders
- City of Fort Collins
- A.O. Smith

Introduction

- Net-zero energy residential communities are crucial for achieving decarbonization goals, but the high-penetration PV in those communities is posing challenges to the distribution grid.
- Traditional design and operation of net-zero communities rely on rule-of-thumb methods and may not work in complex scenarios.
- AI/ML methods can optimally size PV for net-zero energy, identify user preferences and usage patterns, and fully unlock the potential of DERs to address distribution grid issues.

How is AI/ML used in this project

- **PV sizing:** ML-based automated workflow identifies the optimal placement of rooftop PV in a residential community to maximize solar production and operational cost savings.
- **Data-driven learning:** Various data-driven methods were used to identify building models, user preferences, and user behavior to inform decision-making.
- **Control:** Optimization-based control of BTM resources in a residential community to improve grid reliability and resilience.

Challenges and best practices

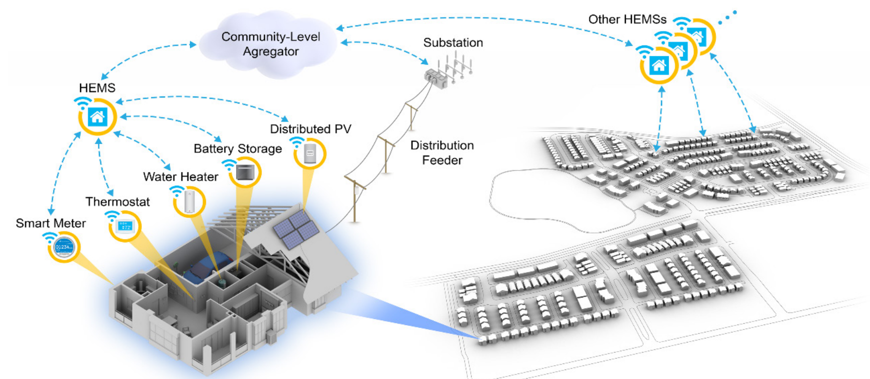
- User preferences and behavior are uncertain. *Solution*: Retrain ML models periodically with a mix of new data and old data and focus on predicting behavior that has a higher impact on control.
- Optimization-based control of a large population of BTM resources is computationally challenging. *Solution*: Formulate the complex problem in a hierarchical manner to make it scalable.

Key takeaways and future work

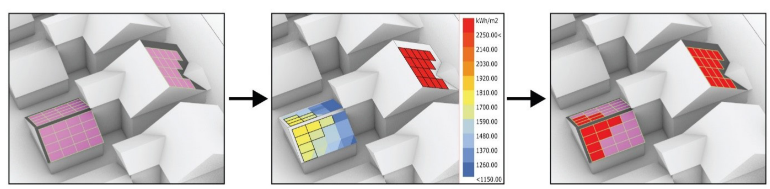
- **Key takeaways**: AI/ML can help residential communities meet the net-zero energy design goal without over sizing the PV and improve grid reliability and resilience through advanced controls.
- **Future work**: Large-scale demonstration in real-world environment under various operational scenarios.

Research Highlights

AI-driven Hierarchical Control for Scalable Management of DERs: HEMS manages each home's behind-the-meter DERs, and community-level aggregators coordinate the HEMS and the grid.

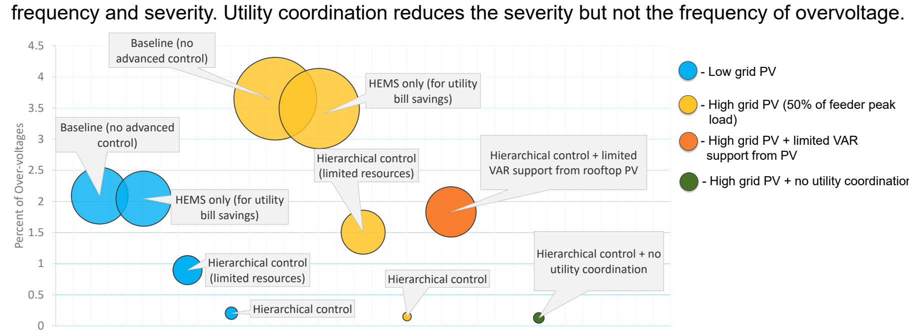


ML-based Optimal Rooftop PV Placement: An automated, ML-based workflow was implemented in architectural design software to optimally place rooftop PV in a residential community to achieve the net-zero energy goal considering roof geometry, orientation, shading, irradiance, etc.



(a) Automated PV panel layout (b) Solar radiation study (c) Panels selection

Addressing overvoltage issues caused by high-penetration PV: Unlike HEMS that focuses on utility bill savings, community aggregators and VAR support effectively reduce the overvoltage frequency and severity. Utility coordination reduces the severity but not the frequency of overvoltage.



Field Demonstration in an Affordable Housing Community: Performed field demonstration in four homes at the Basalt Vista community in Colorado. Achieved 3.1 kW average load reduction and 4.5 kW peak demand reduction during a 5-hour peak period in field experiments.

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