Residential Load Shaping with Transactive Controls

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Background and motivation

- Power demand has large, daily variations that stress the physical system and incur economic inefficiencies.
- Curve flattening during peak hours is achieved by influencing or controlling flexible loads.
- Transactive control uses price signals to communicate the value of reducing load.
- Avoiding direct thermostatic control upholds the privacy of participants.

Technical approach

- Consider a neighborhood of $N$ homes equipped with PV and smart HVAC controllers.
- Objective: minimize the maximum aggregate load during peak hours.
- Build transactive control signals, unique to each home:

  $$p_i(t) = \begin{cases} 
  \lambda_{pre} & \tau_1 \leq t \leq \tau_1 + \tau_2, \\
  \lambda_{peak} & \tau_1 + \tau_2 \leq t \leq \tau_1 + \tau_2 + \tau_3, \\
  \lambda_{base} & \text{otherwise} 
  \end{cases}$$

Conclusion

- Consistent peak reduction over baseline is achieved using a Bayesian Optimization routine.
- Customers experience utility bill price reductions on average.
- Unique factors including high dimensionality, unknown gradients, and expensive evaluations pose challenges for the scalability of this routine that will be further investigated.

Fig. 1. Typical transactive control signal shape

Fig. 2. Customer bill changes
Bayesian Optimization

Challenges
• Load response $\rightarrow$ black-box function
• Slow model $\rightarrow$ expensive evaluations

Bayesian Optimization
• Given prior dataset $D = \{(x_n, y_n) | n =$
Simulation Results

Optimization Algorithm

Set bounds for \( \tau_1, \tau_2, \tau_3 \)

Suggest next \( x = [\tau_1 \ldots \tau_{3N}] \)

Run black-box load forecast model

Evaluate output and calculate \( y|x \)

Update model covariance matrix with \( (x, y) \)

Return \( x_{\text{best}} \)

- The chosen price signals cause a precool around 4p.m. to reduce peak load between 6 – 7p.m.
- Simulations with \( N = 10 \ldots 60 \) homes verifies a 10% or greater peak reduction in the neighborhood
- Overall results show promise for real-time application in neighborhood-level microgrid controller
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