ELECTRICITY SIMULATIONS ON THE DISTRIBUTION EDGE:

Developing a Granular Representation of End-User Electric Load Preferences using Smart Meter Data

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Introduction

The electric distribution grid is transitioning toward a model in which customers can themselves provide a variety of services to the grid, including electricity generation, by investing in distributed energy resources (DERs) such as distributed solar generation, programmable appliances, and energy storage. However, customers' incentives to make these investments depend on how they are being charged for electric service. Specifically, the way the electric distribution company allocates the cost of service into the different elements of the rate (tariff) design, such as volumetric or demand charges and time-variant or flat charges, determines the returns on investment for different types of DERs. The rate design will also be a main factor in determining where and to what extent investment in DERs are made, and whether DERs will contribute to improving system reliability and reducing electric system costs.

Despite the topic's importance for the electric distribution system of the future, the body of literature on the impact of electric rate design on the proliferation of DERs is still limited. In addition, engineering simulation models are generally cost-minimization problems with ad-hoc monetized penalties for deviations from a reference electricity use profile, and, thus, do not provide a very good representation of consumer preferences. In contrast, our model specification provides a granular representation of residential customers' electricity consumption preferences, and can therefore be used to evaluate and compare residential customers' responses to different electric rate designs and their decisions to invest in and operate DERs.

Specifically, our approach is based on including a consumer welfare constraint (i.e., a utility constraint) in an existing simulation (electric bill minimization) model to represent consumer preferences for non-thermal and thermal electric services. This representation allows us to separate consumer preferences related to heating and cooling needs, which are weather dependent, and other electricity services, which depend on individual preferences for appliance usage.

We calibrate the model using hourly AMI data for over 50,000 customers,from a large US electric distribution company by first estimating the thermal portion of the total household load through regression analysis to arrive at household level profiles for non-thermal and thermal (space heating and cooling) electricity loads. We then calibrate the parameters of the utility constraint in our model to replicate the daily load shape of the regression-estimated non-thermal electricity loads, and adjust the model parameters representing the buildings' thermal properties to replicate the regression-estimated space cooling loads.

The results of this research demonstrate the capabilities of our modeling tool for creating large numbers of synthetic end-user profiles that can replicate observed household level load data, relying on a combination of econometric techniques and engineering simulation methods. In future research, we will further improve the calibrations, and then use the resulting individually calibrated preferences to assess how end-users may respond to different electric rate designs by changing their electricity load and investing in DERs.

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