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Incorporating residential AC load control into ancillary service markets: Measurement and settlement

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HIGHLIGHTS

- Many AC load control programs with unused capacity are not part of grid operations.
- A key problem hampering use in grid operations is measurement of load reductions.
- Although commonly used, day-matching baselines are not well-suited to this purpose.
- We compare measurement accuracy of simulated load reductions using various methods.
- We recommend use of load impact tables and a more detailed ex-post evaluation.

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ABSTRACT

Many pre-existing air conditioner load control programs can provide valuable operational flexibility but have not been incorporated into electricity ancillary service markets or grid operations. Multiple demonstrations have shown that residential air conditioner (AC) response can deliver resources quickly and can provide contingency reserves. A key policy hurdle to be overcome before AC load control can be fully incorporated into markets is how to balance the accuracy, cost, and complexity of methods available for the settlement of load curtailment. Overcoming this hurdle requires a means for assessing the accuracy of shorter-term AC load control demand reduction estimation approaches in an unbiased manner. This paper applies such a method to compare the accuracy of approaches varying in cost and complexity – including regression analysis, load matching and control group approaches – using feeder data, household data and AC end-use data. We recommend a practical approach for settlement, relying on an annually updated set of tables, with pre-calculated reduction estimates. These tables allow users to look up the demand reduction per device based on daily maximum temperature, geographic region and hour of day, simplifying settlement and providing a solution to the policy problem presented in this paper.

1. Introduction

Adding variable generation such as wind and solar to an existing power system increases the need for flexible resources to respond to system changes and uncertainties, including wind ramps, demand ramps and forced transmission or generation outages. Flexible resources are defined by the speed in which they can increase (ramp up) or decrease (ramp down) production. Traditionally, much of the system flexibility required to maintain reliability is obtained from peaking generation units. However, using generators to provide operational flexibility can impose significant costs and lead to extra wear and tear on the generating equipment. In 2010, the North American Electric Reliability Council (NERC), which sets reliability standards for operation of the electric grid, investigated emerging flexible resources, including demand response, battery storage and electric vehicles (North American Electric Reliability Council (NERC), 2010). It identified residential air conditioner (AC) response as an existing technology that is particularly valuable because it is typically available during peak load times when energy and ancillary services are expensive and when generation is typically in short supply. The study recommended adjusting regional and federal reliability standards that might limit the deployment of these resources, developing operation infrastructure, and modifying market rules or non-market rules/procedures that limit technically capable resources from providing flexibility. Several markets in North America, including those in Texas, New York, Ontario, and California, are currently in the process for developing standards to incorporate demand response and other emerging flexible resources.

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Residential AC response is particularly well suited for providing operators flexibility and, more specifically, contingency response, which requires fast deployments to stabilize the grid, but are used infrequently (<30 times per year) and for short periods (usually less than 10 min). Recent advances in communications technology allow for more precise control of AC units and operator visibility. Residential AC response is a disseminate resource that is not subject to transmission constraints and can be used to deliver specific incremental load reductions at specific locations. In addition, as we detail below, the operational capability of residential AC load control program and their ability to be used for grid operation has been tested extensively in recent years. It is also a large pre-existing resource that can be incorporated into grid operations through adjustments in reliability standards, market rules, and load control dispatch practices. Based on the Federal Energy Regulatory Commission 2010 Demand Response (DR) survey, there are over 4.8 million households and over 200,000 businesses currently enrolled in AC load control programs (Federal Regulatory Energy Commission, 2011). Historically, these resources have been used for emergency operations and to offset the need to build additional peak generation, but they can also provide operators' significant flexibility if incorporated into ancillary service electricity markets.

To date, there have been several studies that have tested the potential of controlling residential AC loads in order to provide flexible operating reserves and assessed the ability of integrating control of AC loads into operations. The conceptual framework and the policy reasons for using AC as spinning reserves were detailed in a series of reports by the Oakridge and Lawrence Berkeley National Laboratories (Eto et al., 2001, Kueck et al., 2001). In addition, Lawrence Berkeley National Laboratory, Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) sponsored a series of demonstration studies testing the ability to use AC load control to provide operating reserves (Kirby, 2003; Eto et al., 2007; Eto et al., 2009; Sullivan et al., 2009; Gifford et al., 2010).

Combined, the demonstration studies showed that:

- Residential AC load control reduces demand quickly. AC units begin to noticeably shut down or cycle compressors within 60 s of when the load control signal is sent out and reach 80% of capacity within 3 min.
- The effect of short-duration residential AC curtailments on customer comfort is negligible.
- AC load drops can be observed on near real time basis using samples.
- The demand reductions observed in the samples were also observed in the distribution feeder circuits.

A key policy hurdle to be overcome before AC load control can be fully incorporated into markets is how to quickly and accurately measure shorter-term (e.g., ten's of minutes to a couple of hours) demand reductions from residential AC curtailments for settlement. This is an important policy question that will affect the ability of residential AC load control programs to participate in electric markets. The challenge is that measurements for settlement and operations need to be conducted in real time or on a monthly basis—much faster than traditional program evaluations, which are conducted on an annual basis. In addition, measuring demand reductions, sometimes referred to as "negawatts," is an entirely different task than measuring power production. While power production is metered and thus is measured directly, demand reductions cannot be metered. They must be estimated by indirect approaches. In principle, the reduction is simply the difference between electricity use with and without the AC curtailment. However, it is not possible to directly observe or meter what electricity use would have been in the absence of curtailment. Instead, the electricity that would have been used in the absence of the curtailment – the counterfactual, sometimes referred to as the baseline – must be estimated. In doing so, it is important to systematically eliminate or control for alternative explanations for the change in electricity consumption.

Much of the existing research on estimating demand reductions for settlement has focused on large industrial and commercial customers because electricity markets operated by Independent System Operators (ISO) have allowed these customers to participate in energy and capacity markets for well over a decade. The accuracy of many day-matching baselines for settlement of large commercial and industrial customers has been studied on several occasions. In 2003, KEMA compared the accuracy of 6 settlement baselines in 2003 using 646 accounts from multiple regions across the U.S (Coughlin et al., 2008). In 2004, Quantum Consulting and Summit Blue Consulting (2004) estimated the accuracy of 4 settlement baselines using data from 450 accounts in California, none of which were enrolled in DR programs. In 2008, Lawrence Berkeley National Laboratory (2008), (Kema, 2003) compared accuracy of 7 alternate settlement baselines using data from 32 sites in California. It was the first study to assess accuracy by comparing actual and predicted baseline load for demand response program participants. All prior studies had drawn conclusions based on results from non-participants or comparisons of one estimate to another. Since then, assessments of baseline accuracy have relied on the use of proxy event days because this allows a comparison of estimated values to actual known values. Several additional studies have been conducted since, all of which focused on large commercial and industrial customers (Braithwait and Armstrong, 2009; Braithwait and Armstrong, 2010, KEMA, 2011; Bode et al., 2010).

This paper presents a method for assessing the accuracy of shorter-term residential AC load control demand reduction estimation approaches and compares the accuracy of various alternatives for measuring AC reductions using three data sources: feeder data, household data and AC end-use data. The method relies on inserting pre-determined values measured in prior studies into naturally occurring electricity use. It then measures how well each approach estimates (or "predicts") the known demand reductions under different conditions. In total, we evaluate 10 different demand reduction estimation approaches using feeder data, household data and end-use AC data. The approaches tested include both within- and between-subject estimators. Within-subject estimators use customer's electricity use patterns during days when AC units are not curtailed to estimate AC load absent curtailment operations during actual event days, while between-subject estimators rely on an external control group of AC units that is not curtailed to provide information about electricity use absent curtailment.

While highly accurate results are desirable, there is often a tradeoff between simplicity and incremental accuracy. In order to help gauge the benefit of more complex and costly approaches, each of the estimation approaches are compared with one of the simplest and least technical approaches—a set of tables with pre-calculated load reduction estimates. These tables are based on annual evaluations and allow users to look up the demand reduction per device based on the daily maximum temperature, geographic region and hour of day. They facilitate quick settlement when resources are dispatched and provide operators a quick estimate of the DR resources available for operations.

The study presented in this article differs from the studies cited above because it focuses explicitly on the policy problem of how to measure demand reductions from residential AC response. In addition, it compares a wider range of approaches for estimating demand reductions, including day-matching