Enabling Automated Dynamic Demand Response: From Theory to Practice

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ABSTRACT

Demand response (DR) is used in smart grids to shape customer load during peak hours. Automated DR offers utilities a fine grained control and a high degree of confidence in the outcome. However the impact on the customer's comfort means this technique is more suited for industrial and commercial settings than for residential homes. In this paper we present a real-life system for achieving automated controlled DR in a heterogeneous environment. The system is integrated with the USC microgrid. Results show that while on a per building per event basis the accuracy of our prediction and customer selection techniques varies, it performs well on average when considering several events and buildings.

Categories and Subject Descriptors

H.4 [Information Systems]: Information Systems Applications; J.m [Computer Applications]: Miscellaneous

General Terms

Smart Grid; Automated direct demand response platform;

1. INTRODUCTION

With the increasing presence of smart appliances, smart grids have a great opportunity to become ubiquitous in our society. Their unique advantages driven by the bidirectional smart meter communication channel between providers and customers make them suited for energy consumption optimization. Demand Response (DR) is a well known technique used by utilities to shape customers load especially during peak hours when the generation capacity is in danger of being exceeded. Utilities have at their disposal a variety of

techniques including direct control, incentives, or voluntary programs to reduce peak demand.

Direct control is a technique which lets utilities control the customers' appliances directly without relying on incentives or voluntary participation. For this reason it can be seen as intrusive and having a considerable impact on the customer lifestyles. Hence, it seems more suited for offices and industrial complexes than for residential customers. Nonetheless its advantages including fine grained control of the amount of energy to curtail and the ability to efficiently target specific areas and time periods make it suited for further research into how it can be easily and with minimal impact integrated in complex microgrid environments consisting of heterogeneous buildings (e.g., offices, residential apartments, libraries, lecture rooms).

To achieve a customer-tolerated and utility-efficient directly controlled DR numerous factors need to be taken into consideration including: data privacy, customer satisfiability, reliability of the controlled DR action, and fast turnaround time of the decision process. To make things more complicate the DR model widely used nowadays needs to consider more realistic scenarios on when, for how long, by how much, and how (whom to pick) to reduce electricity consumption. We call this decision making process Dynamic DR (D^2R). We have addressed all the above in numerous papers that can be found on our group's website¹.

2. EXPERIMENTAL TESTBED

The USC microgrid, peaking at around 27 MW, is a unique environment to study the impact of direct control in complex social and cultural environments by offering a state-of-the-art control center capable of managing 170 buildings spread across two campuses and totaling more than 50,000 sensors. This makes the USC campus a truly "living laboratory" for advancing Smart Grid research and technology [5]. The USC Facility Management Services (FMS) owns and operates the campus electrical infrastructure which includes two substations and a 3 million gallon Thermal Energy Storage (TES) system complementing the existing chilled water system. FMS has more than 6 years worth of historical and real-time kWh consumption data, gathered from 33 DR enabled buildings, aggregated at 15 minute intervals. Combined with

¹http://ganges.usc.edu/wiki/Smart_Grid

Figure 1: Overview of the complete automated D^2R system.

detailed information on the classes' schedule, buildings' occupancy, and weather data, it offers a unique opportunity to investigate the main challenges and possible solutions to adopting an efficient and reliable controlled DR program in complex dynamic environments. Currently FMS's focus is on HVAC based DR (through Duty Cycling, Variable Frequency Drive, Global Temperature Reset) but upgrades to extend it to other DR techniques such as those based on the lighting system are planned.

The USC microgrid is also a test bed for the LA DWP Smart Grid Demonstration Project (SGRDP) [3] which involves more than 50,000 residential customers in voluntary and controlled (through smart home appliances) DR.

3. SYSTEM REALIZATION

We have bundled our consumption and prediction methods as well as customer and DR strategy selection algorithms in a Demand Decision Support (DDS) API module integrated with FMS's infrastructure.

The USC microgrid communicates with the LA DWP DRAS server [4] through OpenADR [1] messages. Internally, the software infrastructure consists of two main components: the Integrated Building Control (IBC) and our DDS. The former is in charge of controlling buildings through the BACnet protocol [2], while the latter is responsible for the building-strategy selection during each DR event. Figure 1 gives an overview of the system's main components. A typical workflow begins with an LA DWP OpenADR message containing the request details for a DR event (e.g., datetime, duration, curtailment target). For the USC microgrid the duration is always set between 1:00PM and 5:00PM due to the specific LA climate. Once it has received the request, the IBC forwards the details to DDS including additional details such as the list of buildings and associated DR strategies for the given event. DDS then processes the message, performs consumption and curtailment predictions based on historical and real-time data (i.e., consumption, weather, occupancy, etc.), and recommends the building-strategy pairs to be used in DR. This list is sent back to IBC which puts the selected buildings into DR by using the suggested strategies. Information on the achieved curtailment and estimated achievable target is sent back to the LA DWP DRAS every 15 minutes. To ensure a sustainable D^2R a building-strategy reselection is performed hourly. Finally, the outcome of the DR event is sent 15 minutes after its completion, by providing LA DWP with information on the achieved curtailment and the deviation from the initial estimate.

Figure 2: Average MAPE error per event across buildings.

Analysis of over 400 DR events run between 1:00PM and 5:00PM from Nov 2012 to Dec 2014 have shown that our system is capable of achieving low MAPE error per event (cf. Figure 2). Individually, around 49% of buildings had an error less than 10% while 6% were greater than 20%.

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