A Primary Market for Optimizing Power Peak-Load Demand Limits

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ABSTRACT

In this paper the authors propose a market-based mechanism for organizational units of Commercial and Industrial power consumers or companies in a consortium to reduce their peak power demand. The market mechanism requires participants' bids to indicate the value they associate with power needed to run various services, and the power quantity requirement for these services over a time horizon. The market resolution produces peak demand allocation, i.e., determination of the peak demand and the associated cost that the units need to pay. The global peak-demand is then derived by optimizing individual participants' peak demand. The market mechanism is based on decision optimization, and guarantees the formally defined properties of Pareto optimality, Nash equilibrium and benefit distribution fairness.

Keywords: Decision Optimization, Electric Peak Load, Electricity Market, Peak Demand Allocation, Peak Power Demand

INTRODUCTION

Power demand is increasing and so is the cost of procuring it. Power generation companies are reluctant of making large capital investments that expand the capacity which could even make future costs to customers greater. Power companies prefer consistent streamlined consumption which helps maximize their returns. Short spikes in power consumption affect their bottom line by requiring higher capital investment making it more costly to generate and distribute power.

Typically, the cost of electric consumption by Commercial and Industrial (C&I) customers comprises of two factors: amount of Kwh of power consumed; and the maximum peak-demand (Kw) that an organization reaches during a specific contractual consumption period. This peak-demand constitutes a significant part of the electric consumption cost because reaching this peak even for a short period in the past could cause the cost of electricity to skyrocket. Therefore, C&I customers are motivated to reduce their peak demand.

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However, individual units within the C&I organization, which often have autonomy on cost decisions, have little to no motivation to reduce their peak-demand. Therefore, many advantages such as purchasing power collaboratively that could reduce the cost due to economies of scales may not be realized. It could also be more beneficial to individual units to decide on their short term peak demand power internally instead of resorting to exceeding a peak demand limits set by a power company and incur higher penalties. To address this problem, the focus of this paper is to develop an optimization based market mechanism that would incentivize players to decide on peak demand limits which maximize their benefit by increasing their overall utility and reducing their cost.

Consider the George Mason University (GMU) as an example of such a C&I customer. A university usually comprises of different units (e.g. schools, departments, centers, etc.). These units require some services (e.g. lighting, heating, ventilation and air-conditioning (HVAC), etc.) which require electric power to operate. An electric utility company, Dominion Virginia Power, supplies power to the university according to a signed contract which specifies its terms. More specifically, it states the price per Kwh of consumption and an additional cost component for each peak-demand bracket reached during the contractual consumption period. As a result, the higher peak-demand is, the higher the cost will be. The university has an energy manager who is responsible for predicting and setting the maximum consumption anticipated at any given time. In normal circumstances, the energy manager tries to predict the demand for each time period and account for contingencies when setting the peak-demand for a building or a service. Once these limits are set, the university’s energy management system (EMS) takes the control of its power consumption. When the overall maximum peak-load is about to be exceeded, the energy manager faces the responsibility of “load shedding”, i.e., shutting down some services as to not exceed the preset peak demand bound. However, little evaluation of the services to be shut down is made. Moreover, the units benefiting from the services are rarely consulted to determine the real value of the services being shut down.

The purpose of our proposed market framework is that each unit of a C&I organization or any member of a consortium can separately run its services by choosing its own peak-demand budget, which will result in the total value for each unit. Alternatively, units can collaboratively determine their collective peak-demand budget, in lieu of monetary benefit, which also results in the total value (of services plus an extra benefit). The idea is that the exchange of the peak demand budget may result in a higher total value than what could be achieved in the original allocation. The question our framework resolves is (1) how to determine the peak-demand for each participating member, then (2) how to maximize the overall organizational value $\Delta$ by collaboratively selecting the peak demand limit, and (3) how to fairly distribute $\Delta$ among organizational units. More specifically, the contributions of this paper are as follows:

First, we propose and formally define a Peak-Load Demand Market framework. The idea is to create a market or a consortium of players where units of an organization or other organizations who have autonomy on decisions on power. The demand budget represents the right which a unit has to consume up to the specified power bound. Each unit submits a bid, which indicates the services it would like to run, the utility value of each service and the power requirements over a fixed time horizon, e.g., one year. The market resolution mechanism produces a Peak Demand Allocation for each unit, and the payment that the unit needs to make. We also identify desirable properties of the peak demand market, namely Pareto optimality, Nash equilibrium and the benefit distribution fairness defined formally in the paper.

Second, in order to support market resolution, we develop and implement a formal optimization model to decide on the selection
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