Energy and Buildings 112 (2016) 222–233

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Energy Forecasting for Event Venues: Big Data and Prediction Accuracy

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ARTICLE INFO

Article history:
Received 10 July 2015
Received in revised form 20 October 2015
Accepted 8 December 2015
Available online 14 December 2015

Keywords:
Energy prediction
Energy forecasting
Smart meters
Big Data
Sensor-based forecasting
Machine learning

ABSTRACT

Advances in sensor technologies and the proliferation of smart meters have resulted in an explosion of energy-related data sets. These Big Data have created opportunities for development of new energy services and a promise of better energy management and conservation. Sensor-based energy forecasting has been researched in the context of office buildings, schools, and residential buildings. This paper investigates sensor-based forecasting in the context of event-organizing venues, which present an especially difficult scenario due to large variations in consumption caused by the hosted events. Moreover, the significance of the data set size, specifically the impact of temporal granularity, on energy prediction accuracy is explored. Two machine-learning approaches, neural networks (NN) and support vector regression (SVR), were considered together with three data granularities: daily, hourly, and 15 minutes. The approach has been applied to a large entertainment venue located in Ontario, Canada. Daily data intervals resulted in higher consumption prediction accuracy than hourly or 15-min readings, which can be explained by the inability of the hourly and 15-min models to capture random variations. With daily data, the NN model achieved better accuracy than the SVR; however, with hourly and 15-min data, there was no definitive dominance of one approach over another. Accuracy of daily peak demand prediction was significantly higher than accuracy of consumption prediction.

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1. Introduction

Recent advances in sensor technology and the proliferation of smart metering devices that measure, collect, and communicate energy consumption information have created possibilities for development of sophisticated energy services. Big Data collected by smart energy meters have created opportunities to analyze energy use, identify potential savings, customize heating and cooling activities for savings and comfort, measure energy efficiency investments, provide energy cost estimates for real estate buyers, and educate about responsible energy usage and conservation.

This potential has been recognized by governments and industries, which resulted in the Green Button initiative [1]. This initiative is an effort to provide utility consumers with easy and secure access to their energy usage data and the ability to share these data with third parties. Smart meter data are provided to consumers in a standardized Green Button format which facilitates data sharing, integration, and reuse. With the Green Button format, consumers can permit the access of their energy use data to take advantage of the growing range of energy applications, products, and services to help them conserve energy and manage their electricity bills. Presently, over 43 million households and businesses have access to their energy usage data in the Green Button format [2], which creates tremendous possibilities with respect to energy management. London Hydro, the local electrical utility involved with this project, has developed the first cloud based Green Button Connect-My-Data test environment to allow for data access to academic partners with the customer's consent.

A typical premise in data analytics, and especially in Big Data analytics, is that more data have the potential to lead to new insights and better business decisions. This is especially true with machine learning algorithms that can learn better with more data. However, massive data sets pose challenges due to their size and complexity [3,4]. With sensor technologies, we can collect large data sets, but these sets might be difficult to process. This study considers different sensor reading intervals, investigates how more data impact energy forecasting accuracy, and looks into trade-offs between accuracy and processing time.

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http://dx.doi.org/10.1016/j.enbuild.2015.12.010
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Moreover, this work explores the opportunity to use Green Button data to predict electrical energy consumption for large commercial customers, specifically event venues including sports arenas, concert halls, theatres, and conference centers. Such consumers are especially interested in energy forecasting on the event level (a specific concert, game, etc.) because this affects pricing for use of the facility.

Event venues can be expensive facilities to operate; the cost of electricity for sports arena can exceed $3,000 per day [5]. Ice rinks, by their nature, are large electricity consumers with standard arenas using around 1.5 GWh/year [6]. Thus, there have been significant efforts in improving efficiency in ice arenas: several projects provide recommendations on best practices and reduction measures to help reduce their operating costs [6]. Consequently, it is important to address this type of buildings in an energy prediction study. Moreover, forecasting energy consumption in the presence of different events, will assist venue operators to estimate energy cost of future events and it will enable them to include energy cost in the facility usage fee.

This study was oriented to support energy management operations and decision making by Spectra Venue Management at Budweiser Gardens in London, Ontario. This study estimates future energy consumption by considering past energy consumption available through Green Button and contextual information about future events such as event type and schedule. Although the focus is on event-organizing venues, the proposed approach can be used by any consumer that is impacted by some form of operating schedule, such as hotels, conference centers, and schools. Unlike typical sensor-based approaches which rely on energy readings and meteorological information [7,8], this work takes advantage of contextual information in the form of an event schedule and attributes.

It is important to highlight the difference between energy consumption and demand: *consumption* is the total amount of energy used, expressed in KWh, whereas *demand* is the immediate rate of that consumption, often expressed in KW. Commercial consumers are typically charged for both consumption and demand, although the pricing models differ among distribution companies [9]. Consequently, in addition to consumption prediction, commercial consumers are interested in predicting energy demand peaks because lowering these peaks would result in a reduced electricity bill. Therefore, this paper considers consumption and peak demand prediction.

The type of consumer, the event-organizing venue, makes prediction especially challenging. Energy consumption in office buildings [10] usually resembles a very distinctive pattern similar to that shown in Fig. 1, with lower consumption overnight and on weekends. In contrast, the consumption variations of an event-organizing venue, as shown in Fig. 2, are much larger and do not

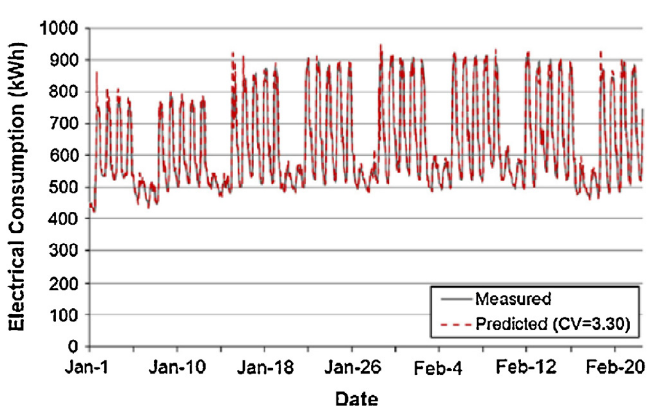

Fig. 1. Building energy consumption [11].

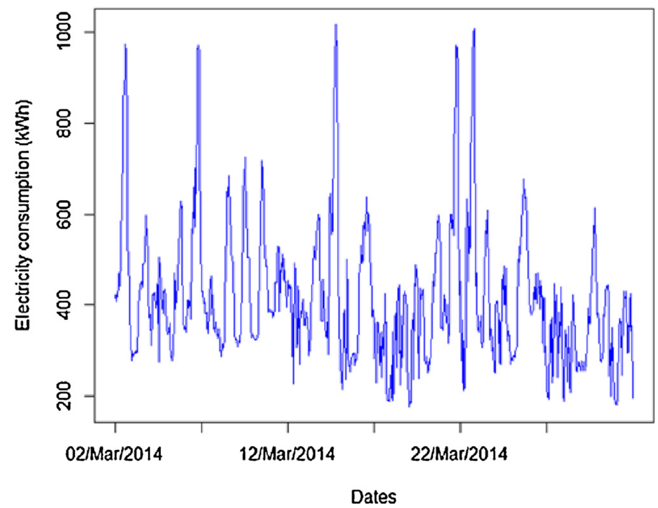

Fig. 2. Event venue energy consumption.

exhibit a strict pattern similar to those of office buildings. Consumption increases during an event, and the actual pattern and magnitude are related to the event attributes such as type (hockey, basketball, . . .) and seating configuration.

Because of the challenges described, it is expected that prediction accuracy will not be as high as for residential buildings or offices; however, it is important to address this category of consumers.

The rest of this paper is organized as follows: Section 2 reviews related work, and Section 3 introduces neural networks, support vector regression, and performance metrics. The methodology, including the data set, the prediction models studied, and model building, is described in Section 4. An evaluation is presented in Section 5, and Section 6 concludes the paper.

2. Related Work

A large number of research studies have addressed various aspects of electrical energy prediction such as a nation's annual electricity consumption [12], the annual energy consumption of an industry sector [13], the annual energy consumption of the residential sector [14], and daily or hourly energy demand using smart metering technology [11,15].

Annual electrical energy consumption has been found to be related to population growth, economic growth, energy prices, energy intensity, and other factors [16]. Estimating annual energy consumption on a national or regional level is important for planning electrical production capacity; however, annual consumption does not account for demand peaks, and the generation capacity needs to be able to provide for these peak demands. Moreover, annual energy consumption prediction has very limited relevance to energy conservation efforts. Wholesale market prices for electricity are driven by a supply-demand relation, which further increases the need to predict demand variations.

The interest in demand prediction together with the proliferation of smart metering has resulted in a shift in forecasting efforts to daily and hourly consumption prediction [11,15]. This paper explores daily, hourly, and 15-min interval prediction for consumption and peak demand and compares their accuracy.

The work of Jain *et al.* [11], like this paper, explored the impact of temporal granularity (daily, hourly, 10-min intervals) on the accuracy of electricity consumption forecasting. They achieved the best results with hourly intervals and monitoring by floor level. However, whereas Jain *et al.* studied a residential building, this

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