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Research Paper

# A study on estimation of aggregated electricity demand for one-hour-ahead forecast

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## HIGHLIGHTS

- A method of estimating aggregated households' electricity demand is proposed.
- Using only about 5–10% of households as representative data for estimation.
- Although this model is very simple, successful estimation result is achieved.

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## ABSTRACT

Japanese electricity retail market is fully liberalized in April 2016 and new entry electricity supplier companies make an electricity supply schedule, which target several hundred or more of households. A real time measurement (or now-casting) of the aggregated electricity demand of all households or all distributed micro generation's outputs are important for them to reduce the electricity supply and demand imbalance. They are able to do it by totaling each household's demand data or each micro generation power output data that are measured by smart meters or energy management system. However, it seems very costly to now-cast the electricity demand of several hundred or more of households because they need to process a large amount of data.

For reducing such processing loads, we have been developing an "upscaling model" which estimates the aggregated electricity demand of several hundred households using a small number of representative households' electricity demand. The proposed upscaling model consists of a method of selecting representative households and a method of estimating aggregated demand.

In this paper, we modify the upscaling model that is proposed in our preceding study. In addition, we combine the upscaling model with one-hour-ahead forecast model to modify the forecasted electricity demand by a day-ahead forecast model.



## 1. Introduction

Japanese electricity retail market is fully liberalized in April 2016 [1,2] and new rule of electricity grid operation is implemented. New entry electricity companies are applied as electricity generation companies or electricity supplier companies. In a daily operation, first, supplier companies with residential customers need to schedule a day-ahead supplying and procuring plans that targets several hundred or more of households. They use these plans for a day-ahead spot market trade and generation planning. Then, at the operation day, supplier companies modify the supplying and procuring plans considering the change of whether conditions or customers' behaviours and submit the modified (final) operation plan to general transmission & distribution companies one hour before the actual operation. Before they submit final operation plan, they are able to trade surplus or shortage electricity at one-hour-ahead market.

For optimizing final operation plans, it is important for supplier companies to know electricity supply and demand balance in real time and to forecast one-hour-ahead electricity demand accurately.

In near future, after smart meters are installed in residential sector [3], supplier companies are able to know aggregated electricity balance of supply and demand by totaling each household's

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demand or each generated power of micro generation. However, it seems very costly to now-cast the electricity demand of several hundred or more households because supplier companies need to process a large amount of electricity demand data.

For reducing such processing loads, we propose an "upscaling model" which estimates the aggregated electricity demand in several hundred or more of households using a small number of representative households' demand [4,5]. By using this model, supplier companies are able to know total aggregated electricity demand in real time.

The concept of upscaling model is similar to now-cast total outputs from large number of distributed renewable energy system in utility grid system [6–8]. However, the method of upscaling model for electricity demand of households is not subjected in earlier studies. Therefore, in Ref. [5], we propose the upscaling model for residential electricity demand and discuss some possibilities of reducing forecast error.

In this paper, we modify the upscaling model that is proposed in Ref. [5] and combine with simple one hour forecast model to modify day-ahead forecasted electricity demand which we developed in Ref. [9].

## 2. Electricity demand data

### 2.1. Measurement

In this paper, we use 30 min average electricity demand data measured at about 700 single-family households in Japan [4]. Measured households are spread out all over Japan from Kyushu area to Tohoku area. Measurement period is from 2012/7/1 to 2013/7/31. Because there are some data losses, data available dates are different among households. Therefore, the number of data available households varies with days. Average total households number in each day is around 400–500.

### 2.2. Electricity demand characteristics

In this paper, the real-time estimation target is the average electricity demand of all households. Fig. 1 shows daily average, maximum and minimum electricity demand in average electricity demand of all households. Annual average of daily average electricity demand is 719 W (=17.2 kW h/day). It is larger than Japanese average household (around 500–600 W) [10]. As shown in Fig. 1, the average electricity demand of all households is most fluctuated in winter, so that in that season, it is expected that accurate forecasting is difficult.

## 3. Methods of upscaling model

As we proposed in Ref. [5], the upscaling model consists of the selection of representative households and the estimation of aggregated electricity demand of all households. In this chapter, first, we determine requirements of representative household. Then we introduce how to select representative households and estimating aggregated electricity demand.

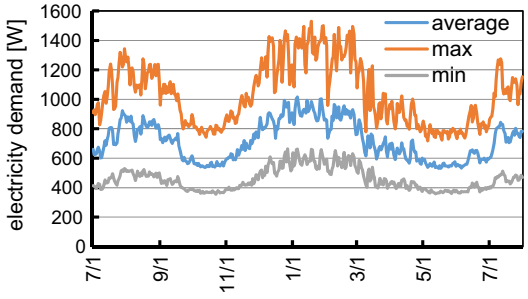


**Fig. 1.** Daily average, maximum and minimum electricity demand of all households.

### 3.1. Requirements of representative household

Supplier companies calculate all household's electricity fee at the end of each month, so that they are able to know all households' electricity demand and total aggregated electricity demand at the beginning of each month. Therefore, in this study, representative households are selected at beginning of each estimating month by using electricity data of the last month.

In order to avoid the problem with missing data, representative households need to satisfy following two requirements:

- In the last month, the data is available on 80% days or more.
- In the estimating month, the data is unavailable on only one day or less.

Data availability of each day is judged weather the electricity data is measured in every 30 min completely. If there is one or more records of missing data, that day is judged as data unavailable day. These requirements are determined to avoid bad influences of irregular data conditions such as missing data of some representative households in daily estimation.

Because electricity demand data in each household is measured by smart meter in near future, it is expected that missing data can be avoided. Therefore, these requirements are unnecessary in the actual operation.

### 3.2. Selecting representative households

Households that have similar electricity demand pattern with average pattern of all households should be selected as a representative household. As the criteria for selecting representative households, we use monthly Mean Absolute Error (MAE) relative to average electricity demand of all households by Eq. (1) shown below:

$$MAE = \frac{1}{n}\sum_{d=1}^{n}\frac{\sum_{t=1}^{48}|P_i(t) - P_{all}(t)|}{\sum_{t=1}^{48}P_{all}(t)} \times 100[\%] \quad (1)$$

where $P_i$ is representative households electricity demand, $P_{all}$ is average electricity demand of all households, n is the number of days in the last month.

Households with low MAE is expected to have similar demand pattern with average pattern of all households. The selection is done at the beginning of each month in the following procedure:

(i) Calculate MAE for each household
(ii) Sort households in ascending order of MAE
(iii) Select X households of low MAE as representative households. The appropriate number of representative households X is discussed below.

### 3.3. Methods of estimating the aggregated electricity

We propose two methods for estimating the aggregated electricity. In these cases below, if the estimating day is weekday, "a day before estimating day" means the latest weekday. If the estimating day is weekend or holiday, "a day before estimating day" means the latest weekend or holiday.

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