Electric Demand Prediction for Electricity Market

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Abstract

In Japan, household electricity market is going to be liberalized in 2016. [1] After the liberalization, the needs of demand and supply adjustment by demand sides will rise. Concretely speaking, electric trading style in which demand sides buy electricity on the basis of a demand prediction will be more common in Japan. In this study, we proposed the method of hourly or half-hourly electric demand prediction of the following day in order to control the balance between supply and demand through the electric power system, and test the accuracy of the method by applying it to 2 demand data. One data is the aggregated demand data of the whole consumers contracting with TEPCO (Tokyo Electric Power Company, contracting with about 29 million consumers), and the other data is the household demand data aggregating about 400 households in Kyushu, Japan. The former data is collected every hours, and the latter one is collected every 30 minutes. In the case study using TEPCO data, we cloud predict the demand curve with 3.08% error. On the other hand, in the household case, the error is bigger than 10%.

1 Introduction

In Japan, household electricity market is going to be liberalized in 2016. After the liberalization, the needs of demand and supply adjustment by demand sides will rise. Concretely speaking, electric trading style in which demand sides buy electricity on the basis of a demand prediction will be more common in Japan. In this study, we imagine an electricity trading in which demand side buys its favorite electricity for the following day, such as the clean electricity generated by renewable energy or cheap electricity generated by thermal power generation, in an electricity future market. A precise demand prediction is needed after the liberalization in order to prevent consumers' buying electricity too much or running short of electricity, and to control the balance between supply and demand through the electric power system.

As a preceding study, there are predicting methods using multiple regression analysis, artificial intelligence like neural network or SVM, and time series analysis like MA method or ARIMA method. [2][3][4][5] Predicting methods using neural network is too complex to be said as easy-to-use. [6] To predict the electric demand curve of the following day, using regression analysis which only needs forecasted weather data of the following day as an input is appropriate from aspect of easiness. Few study using regression analysis predicts demand of whole step in a long span. For example, Hatita [2] only predict maximum demand of days. In this study, we will propose the method of hourly or half-hourly electric demand prediction of the following day which is easy-to-use, and test the accuracy of the method by applying it to 2 cases.

This demand prediction method consists of two parts. One is a prediction of an aggregate electric demand of a day, and the other is a prediction of an electric demand curve of a day. In the daily demand prediction, we divide day data into 4 season clusters using k-means algorism according to the average temperature of the day, and then use multivariate analysis considering the day of the week and weather data, such as temperature and humidity. In the demand curve prediction, we divide day data into 6 clusters using k-means algorism, and then calculate a base demand and an average peak pattern of every combinations of cluster and week of the day.

Also, we did case studies to test the effectiveness of this method using the real demand data. One data is the aggregated demand data of the whole consumers contracting with TEPCO (Tokyo Electric Power Company, contracting with about 29 million consumers), and the other data is the household demand data aggregating about 400 households in Kyushu, Japan. The former data is collected every hours, and the latter one is collected every 30 minutes.

2 Electric demand prediction method

This demand prediction method consists of two sub-methods. One is a prediction of an aggregate electric demand of a day, and the other is a prediction of an electric demand curve of a day. Each method needs past demand data, weather data, and calendar information as an inputs.

One-day aggregated demand prediction

One day aggregated demand prediction is done through the flow below. (Fig. 1)

(1) Dividing past day data into 4 clusters
(2) Making demand predicting function of each cluster
(3) Predicting one-day aggregated demand
(4) Modifying prediction error

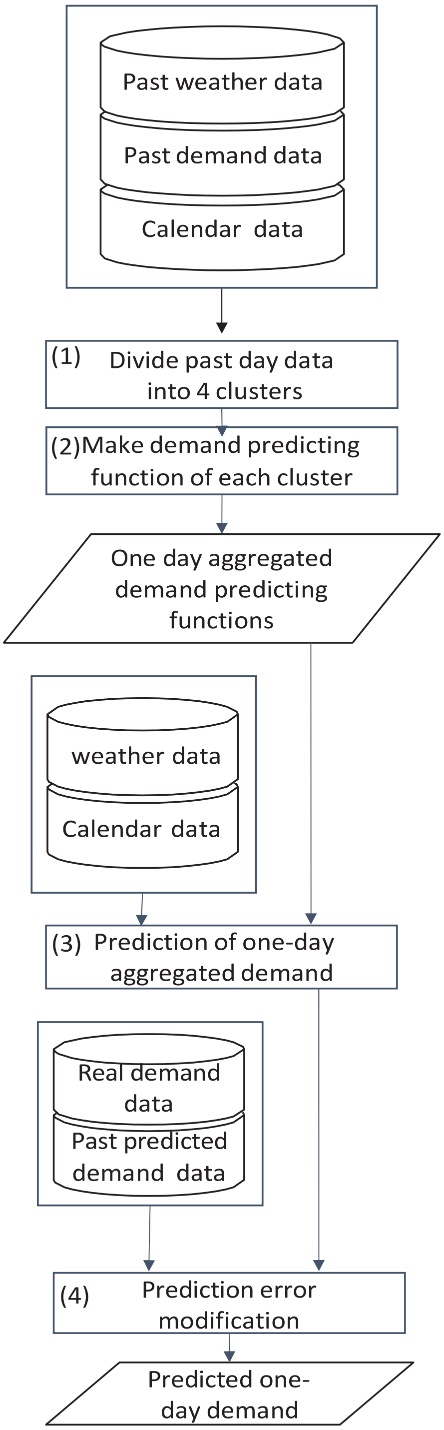

Fig. 1 Flow of one-day aggregated demand prediction

(1) Dividing past day data into 4 clusters
A large amount of electric demand is a demand for air conditioning in Japan. Therefore, one day electric demand has a strong connection with a temperature of the day. In this method, we divide past day data into 4 clusters using k-means algorism according to the average temperature of the day and the average temperature of the previous day and 2 days before.

(2) Making demand predicting function of each cluster
As to every cluster, we do multivariate analysis considering the day of the week and weather data, such as temperature and humidity. One-day aggregated demand predicting function is described as Equation (1), (2), and (3). The electricity using tendency in holiday is considered to be unusual. For that reason, we granted holiday (including the year-end, New Year holidays, and Bon vacation) as Sunday, and the day before holiday as Friday.

$$D_{day}(d) = (WE(d) + WD(d) + a) \quad (1)$$

$$WE(d) = \sum_{i=1}^{l} b_i X_i \quad (2)$$

$$WD(d) = \sum_{i=1}^{m} c_i U_i \quad (3)$$

$D_{day}(d)$: one-day aggregated demand of day d
a, b_i, c_i : regression coefficient
$WE(d)$: weather contributing factor
$WD(d)$: week-day contributing factor
X_i : meteorological variable such as temperature
U_i : weekday dummy variable (0 or 1)
l : the number of meteorological variable
m : the number of weekday -1

As weather contributing factors, we introduce temperature, the square of temperature, and humidity. Using method of least squares, we estimate the regression coefficients and make one-day aggregated demand predicting function of each cluster.

(3) Predicting one-day aggregated demand
When we predict a certain day's electric demand, we first evaluate which cluster the day belongs to according to the average temperature of the day and the average temperature of the previous day and 2 days before, and then substitute weather and calendar information of the day for the variables in predicting function. Because real weather data of a certain day can't be obtained in the previous day, we use forecasted weather data when we use this algorism actually.

(4) Modifying prediction error
In this research, we described one-day aggregated demand predicting function as a function which has only weather contributing factor and week-day contributing factor. In case that another factor get more influential to electric demand, modifying prediction error is done by Equation (4).

$$DF_{day}(d) = D_{day}(d) + \left(RD_{day}(d_{before}) - D_{day}(d_{before})\right) \quad (4)$$

$DF_{day}(d)$: modified one-day predicted demand of day d

$D_{day}(d)$: unmodified one-day predicted demand of day d

d_{before}: the day before day d in the same cluster

$RD_{day}(d)$: real one-day demand of day d

Prediction of an electric demand curve of a day

At this step, Prediction of step-by-step electric demand is done. Prediction of an electric demand curve of a day is done through the flow below. (Fig. 2) This prediction requires predicted one-day aggregated demand as an input in addition to past demand data, weather data, and calendar information.

(1) Dividing day data into 42 clusters
(2) Calculating base demand of each clusters
(3) Calculating peak pattern of each clusters
(4) Prediction of demand curve of a day

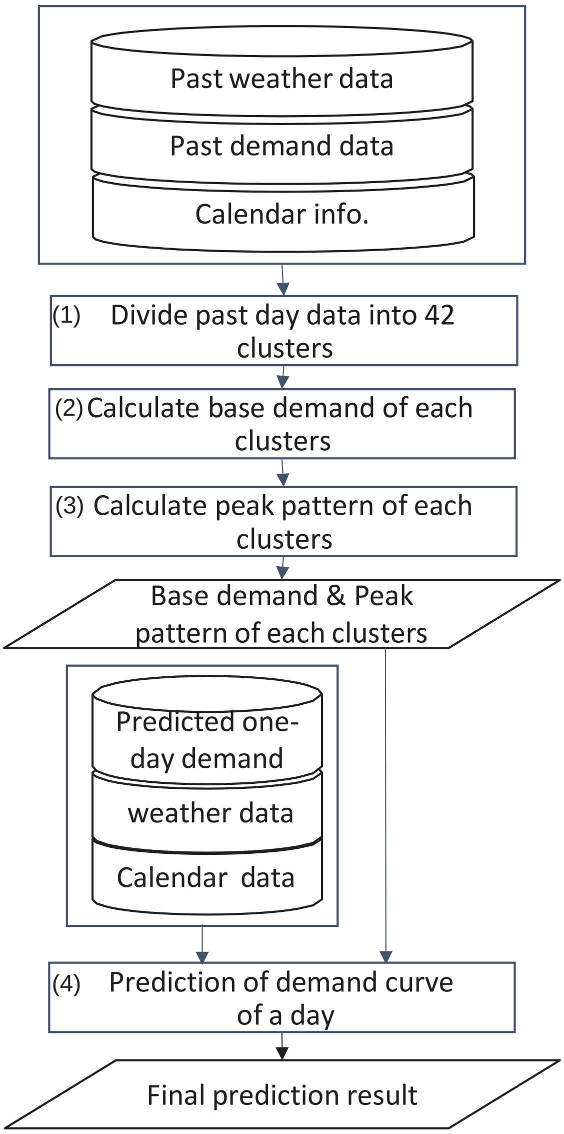

Fig. 2 Flow of prediction of demand curve of a day

(1) Dividing day data into 42 clusters
In order to collect similar demand pattern curve, we first divide past day data into 6 clusters using k-means algorism according to the average temperature of the day and the average temperature of the previous day and 2 days before. And then, we divide each cluster into 7 clusters by week of the day, making 42 clusters totally.

(2) Calculating base demand of each clusters
Demand curves classified in a certain cluster has similar shape. They have same peak time, but the height of their peak is different to each other. Fig. 3 is demand curves (TEPCO's data) which is classified in a certain cluster (Saturday of hottest season). A maximum demand is siding in a wider range according to the one-day aggregated demand than a minimum demand.

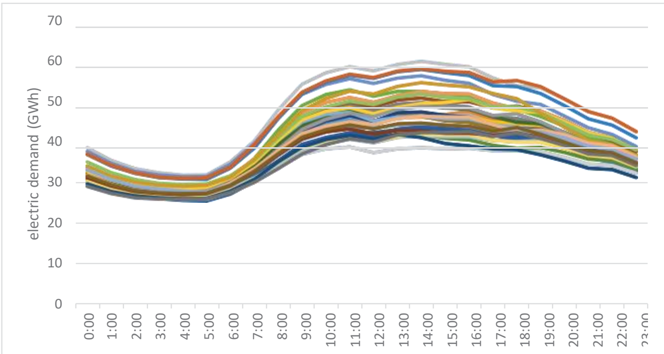

Fig. 3 Electric demand curves classified in a certain cluster

To express this difference, in this study, we describe electric demand curve of a day as the sum of "base demand" and "peak pattern" (as shown by Fig. 4). "Base demand" is a constant number and "peak pattern" is a ratio indicates how to distribute surplus demand to a period of time (sum of all periods of a day will be 1). Both are shared in the same cluster.

Calculation of base demand is done with regression analysis as to each cluster. We express the minimum value of step-demand in a day as regression formula which has a value of one-day demand as a variable (Equation (5)). Then, using method of least squares, we estimate the valuables for each cluster's formula, and set the base demand of the cluster to the value of constant term of the formula.

$$MIN = B + A\, D_{day}(d) \quad (5)$$

MIN : the minimum value of step-demand in a day
B : regression coefficient (= base demand of the cluster)
A : regression coefficient
$D_{day}(d)$: one-day aggregated demand of day d

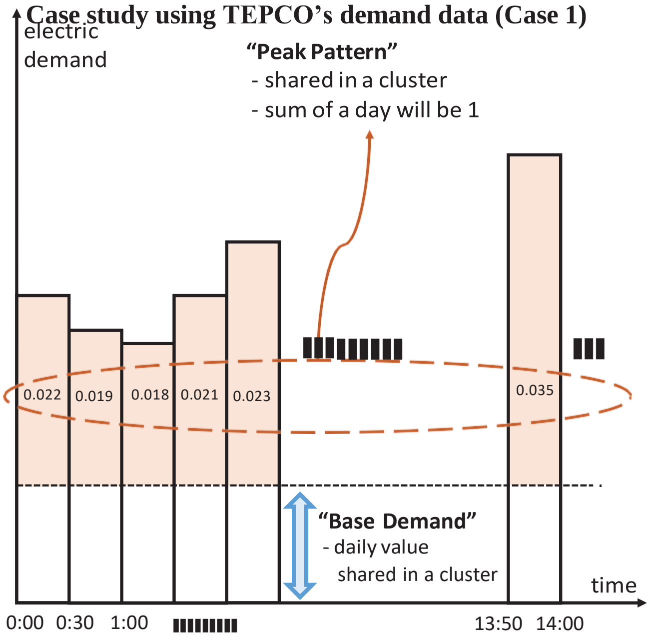

Fig. 4 "base demand" and "peak pattern"

(3) Calculating peak pattern of each clusters
After calculating base demand of the day, calculation of peak pattern is done for every day in the same cluster and average of them is decided as a peak pattern of the cluster.

(4) Prediction of demand curve of a day
Through some steps before, we has made base demand and peak pattern data for every clusters. To predict demand curve of a certain day, we first look which cluster the day belong to according to the average temperature of the day and the average temperature of the previous day and 2 days before. After that, we distribute the surplus of demand (subtract base demands from one-day aggregated demand) by accordance with peak pattern of the cluster.

3 Case studies

We did case studies to test the effectiveness of this demand prediction method using the real demand data. One data is the aggregated demand data of the whole consumers contracting with TEPCO (Tokyo Electric Power Company, contracting with about 29 million consumers) [8], and the other data is the household demand data aggregating about 400 households in Kyushu, Japan. The former data is collected every hours, and the latter one is collected every 30 minutes. Weather data which is used in this research is published by Japan Meteorological Agency (JMA) [7]. Although we use forecasted weather data when we use this prediction algorism actually, we can't obtain the weather data which was forecasted in the previous day. Therefore, we used the actual measured value as an input weather data.

Case study using TEPCO's demand data (Case 1)

We predicted the demand of the whole consumers contracting with TEPCO (Tokyo Electric Power Company, contracting with about 29 million consumers) with this prediction method. This data is publicly-available on TEPCO's web page [7]. Because this data is collected every hours, we granted an hour as one minimum step. As a weather data (temperature and humidity), we used data collected by Tokyo observatory of JMA. We predicted an electric demand of 2012 from demand and data of a span from 2009 to 2011.

The prediction result of one-day aggregated demand is shown by Fig. 5. A cumulo-absolute error of one-day aggregated demand prediction was 1.96%.

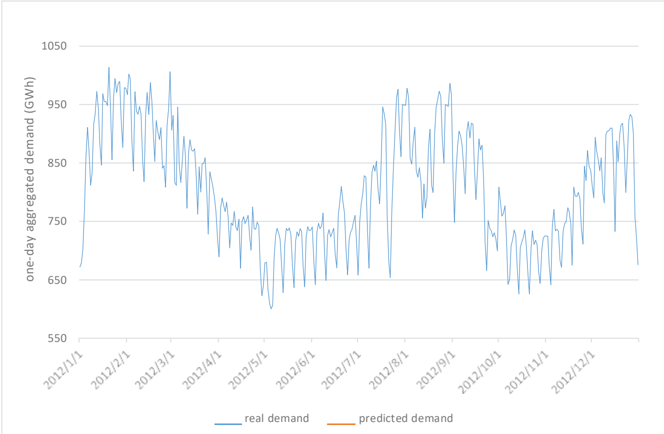

Fig. 5 Prediction result of one-day demand (TEPCO's data)

A cumulo-absolute error of the final prediction result was 3.08%. Prediction result of a certain day is shown by Fig. 7, Fig. 8, and Fig. 9 (mid-term, summer, and winter season). These show that predicted demand curve is similar to real curve.

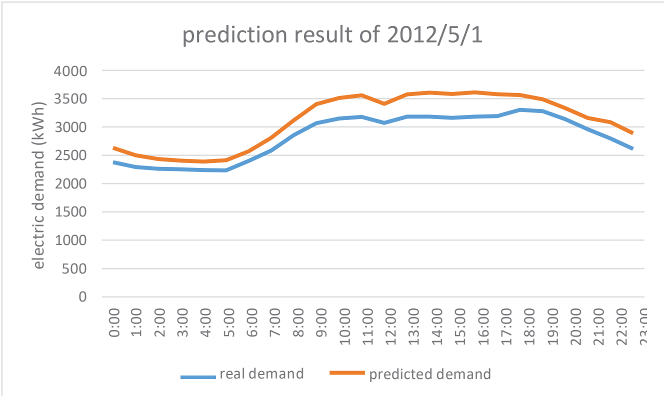

Fig. 6 prediction result of a day in mid-term season

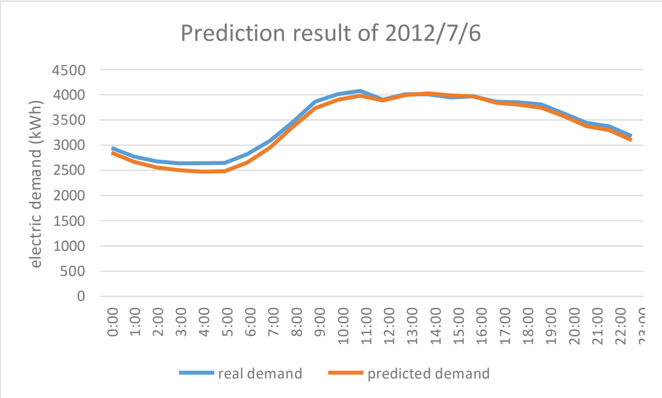

Fig. 7 Prediction result of a day in summer season

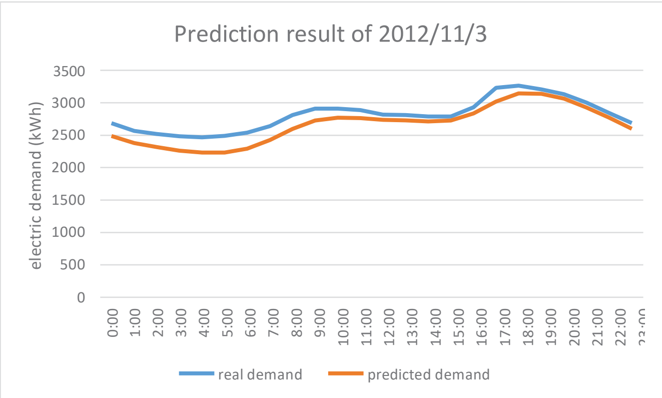

Fig. 8 Prediction result of a day in winter season

Case study using Kyushu household data (Case 2)

We predicted the household demand data aggregating about 400 households in Kyushu, Japan. This data is contributed by Kyushu Electric Power Company (KEP). This data is collected every 30 minutes, and we granted 30 minutes as one minimum step. As a weather data, we used data collected by Hukuoka observatory of JMA. We predicted an electric demand of a span from April 2013 to Dec. 2013, using demand data of a span from April 2012 to March 2013.

The prediction result of one-day aggregated demand is shown by Fig. 9. A cumulo-absolute error of one-day aggregated demand prediction was 3.94%.

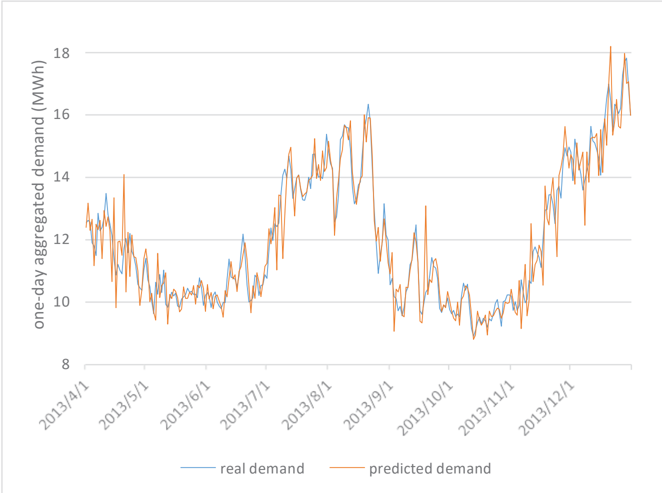

Fig. 9 Prediction result of one-day demand (household data)

A cumulo-absolute error of the final prediction result was 10.3%. Prediction result of a certain day is shown by Fig. 10, Fig. 11, and Fig. 12 (mid-term, summer, and winter season). Predicted demands curve is less similar to the original curve than case 1, it is because of the higher volatility of the curves.

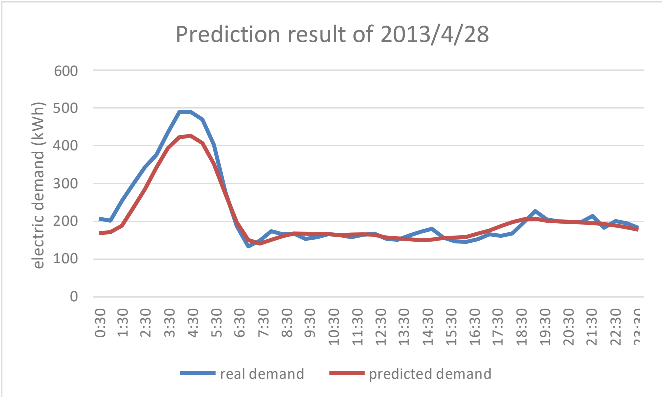

Fig. 10 Prediction result of a day in mid-term season

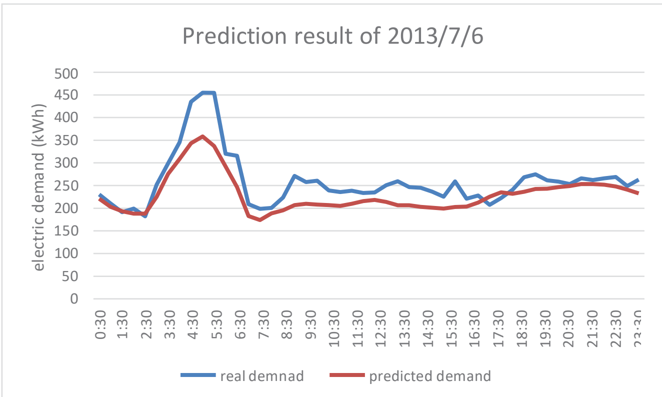

Fig. 11 Prediction result of a day in summer season

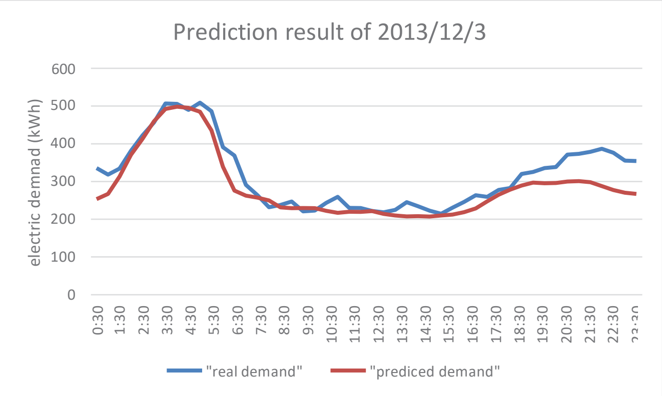

Fig. 12 Prediction result of a day in winter season

4 Conclusions

In this study, we proposed the method of hourly or half-hourly electric demand prediction of the following day which is easy-to-use, and test the accuracy of the method by applying it to 2 cases. In case 1, we predicted the aggregated demand data of the whole consumers contracting with TEPCO (Tokyo Electric Power Company, contracting with about 29 million consumers). In case 2, we predicted the household demand data aggregating about 400 households in Kyushu, Japan. In case 1, we cloud predict the one day aggregated demand with 1.96% error, and the demand curve with 3.08% error. On the other hand, in case 2, one day demand's error was 3.94% and the last demand error is bigger than 10%.

The fact that the prediction error is bigger in case 2 is caused by the less consumers that compose the demand. The less the consumers are, the higher the volatility of the demand curve becomes to be.

Compering two case studies, gap of a cumulo-absolute error is much bigger as to final prediction result than result of one-day demand prediction. Therefore, the method of demand curve prediction has more to be improved than that of one-day demand prediction. The prediction of demand curve of a day has worked to some extent in Case 1, but it can't be said that it worked very well in case 2. It may work if we build some algorism that changes the number of clusters in a demand curve prediction according to the number of consumers that compose the demand.

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